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THE STUDY OF PHYSICAL ASTRONOMY—ITS PLACE IN OUR UNIVERSITIES AND COLLEGES.

T. J. J. SEE.

FOR POPULAR ASTRONOMY.

Having pointed out in a preceding article some of the reasons why physical astronomy should be more carefully cultivated in the United States, we shall now briefly consider this subject in its educational aspect. It may indeed seem strange that there should be any discussion about the educational value of physical astronomy, the science of Newton, Laplace and Gauss, and especially as the great importance of this branch of astronomy is fully recognized at all the leading universities of Europe, where the chairs of astronomy are devoted almost entirely to the mathematical side of the subject. Yet it appears probable that the unfortunate example which has been set in this country by certain of the older universities, which would naturally be expected to direct the educational policy of institutions of learning, has been more or less felt at all of our universities and colleges; and hence when the serious study of astronomy began to be neglected in one or two of the older centres, if it did not languish all over the country, it at least made no distinct progress. The comparative neglect of serious astronomical study would not of itself be so great an evil, were it not for the fact that there are a considerable number of persons in the country who are presumably well qualified as teachers, who ought to inspire serious scientific study, but who, for some reason, have made and are making only the slightest impression upon the students of our colleges and universities. A part of the consequent apathy of students to scientific work doubtless arises from the general commercial and materialistic tendency of the age, but is not a larger part of it traceable to lack of energy, lack of courage and enthusiasm on the part of the professors of astronomy?

The ingenious but flimsy excuse is made that astronomy has no great value as a "culture study" (whatever that may mean!) that it is difficult and our students are lazy and hence they do not take kindly to any study which requires serious sustained intellectual effort. We do not believe that American students are

more given to indolence than are European students; for this certainly could not be true of any students except those who have been raised up in luxury and idleness, and this misfortune has overtaken only a small per cent of the young men who attend our universities. The cause of the neglect of astronomical study must therefore lie either in defective teaching, or in false standards as to the relative value of different studies, or in both. Some may claim that American students are practical, and take most kindly to studies which are not so ideal as astronomy, to studies which have a better pecuniary aspect. The same claim could be made for such studies as Physics, Mathematics and Greek, and it would be as true in Europe as in America, and yet it is doubtful whether any one of these highly ideal subjects is so badly neglected as astronomy.

It is perhaps unfortunately true that most purely scientific studies suffer from the commercial craze of the age, but we can trace the neglect of the exact sciences more to false standards of learning, and to the timidity of those representing the exact and beautiful but difficult sciences like astronomy, than to any other cause. Though it is not our object to discuss the large subject of education in its many aspects and phases, we may state a result which will be recognized by those familiar with educational history as embodying the dicision of the ages, viz.: *That when we consider educational subjects from their intellectual and moral aspects, only those subjects are valuable which are difficult, and in general the value is greater in proportion to the difficulty.*

Of course no utilitarian consideration can have any weight in a true educational policy; genuine culture is concerned only with developing intellectual and moral strength, the power of thinking and of acting; and although the knowledge gained may be useful, this can never be made a principal object, and for that very reason science and art, the idealities of life, differ from the crude realities of business and of nature. Hence the highly ideal study of science and of art has an uplifting influence, in raising us above the miseries of terrestrial existence, and therefore since the time of Plato has been numbered among those activities which are most worthy of the human mind.

It is not without excellent reason that the principal governments of the world prescribe a mathematical curriculum in their military schools; a curriculum made up of those studies which conduce most strongly to clear thinking and to courageous action. Therefore mathematics and the mathematical sciences, like astronomy and physics, make up the principal part of the curric-

ula of military schools; the same kind of study is pursued in the German Gymnasia and once prevailed in the older colleges of this country. At present, however, for some cause, a different policy has been and is being introduced into most of the colleges of the United States, according to which students are to prefer Zoology, Botany, Geology, Anthropology, Psychology, Sociology, Political Economy, Political Science, History, Literature, etc., (in short the inexact sciences and the easy subjects requiring chiefly prodigous memory!) rather than the exact sciences, sciences based on mathematics, requiring correct thinking, and in which something can be known with certainty. In the exact sciences like Mathematics, Astronomy, Physics and Chemistry, theories are based on mathematical methods and are proved by observation; the reasoning is constantly checked by the comparison of theory with phenomena, and in this way real physical laws are detected and established which enable us to predict future phenomena with mathematical certainty.

From an educational point of view it must be conceded that what is known and certain offers an infinitely better *discipline* than what is nebulous and obscure; and after all *discipline in thinking*, not knowledge of facts, is the principal object of true education, for this alone will enable us to form just, enlightened and correct conclusions on all the problems of life.

Therefore in any true educational policy, mathematics and the mathematical sciences must stand first in the order of scientific discipline; languages as a means of thinking and for literary reasons must of course be studied, but space will not permit us to discuss so large a subject here.

Now it is generally conceded by the most eminent authorities of the age that the mathematical sciences are more difficult than even pure mathematics. Physical astronomy and mathematical physics share this difficulty in the highest degree; because while in mathematics we may suppose anything we please so long as our assumptions are not inconsistent in themselves; in astronomy and physics on the other hand our assumptions and hypotheses must be made to conform to the actual conditions and laws of the universe. In other words, astronomy and physics have practically all the difficulties inherent in pure mathematics, besides those arising from complicated conditions and the operation of exact physical laws which underlie the processes of nature. May we not, therefore, justly claim that physical astronomy and mathematical physics are the most difficult, the most austere and the most exalted studies which can engage the attention of man?

If such is their difficulty, and the more difficult studies are the more valuable educationally, it follows that astronomy and physics ought to be assigned a higher place than even pure mathematics. And yet all recognize the claims of mathematics to a high place in any good educational system, and a similar position is assigned to mathematical astronomy and mathematical physics in the great universities of Europe. Is it possible that Americans will neglect the reasoning of Newton and Laplace, Gauss and Gyldèn, Thomson and Helmholtz and prefer instead studies on crayfish and butterflies, social evolution and criminology, Nineteenth Century fiction and woman suffrage? Shall we turn away from the *Principia* and the *Mécanique Céleste*, the greatest monuments ever reared by the human mind, and fix our attention on the latest fads in Biology and Sociology, Photography and Theosophy? Laplace has well said that "astronomy by the dignity of its object and the perfection of its theories is the most beautiful monument of the human mind, and the most noble title of its intelligence." If this perfect and exalted science to which have been devoted the lives of the most illustrious of the human race, to which the greatest discoveries of modern times are due, and by which the fortunes of the world have been so much improved, with its glorious history and the natural prestige of ages, shall in our country sink into educational obscurity, who will be to blame but faint-hearted American astronomers?

We believe that the deliberate judgment of the American people will lead them to give physical astronomy a higher place in our institutions of learning. It seems clear that while all our students of science should know something of physical astronomy, something of the working of the great law of gravitation, the most splendid triumph of the human intellect; those who are to become professional astronomers ought to study profoundly the great questions of the *Mécanique Céleste*: The mechanics of a system of bodies subjected to their mutual attraction, the motions of the planets and the Moon, their periodic and secular perturbations, the long period inequalities and the stability of the planetary system; the motions of the planets about their centres of inertia, precession and nutation; the attractions and figures of the planets, equilibrium of rotating masses of fluid, and of the rings of Saturn; the contraction theory of solar heat, the secular action of a resisting medium and of tidal friction; the oscillations of the fluids which cover the planets, the theory of bodily tides in relation to cosmogony, and the capture theory of comets.

These questions, and the problems to which they lead, must be regarded as the sublimest which have ever occupied the mind of man, and he who is not inspired by their contemplation, and by the memory of the two great men who founded Celestial Mechanics must indeed be incapable of scientific vitality.

One popular error is so wide-spread that it may not be out of place to call attention to it, partly in explanation of the present condition of American astronomy, and partly in order that so great a folly may not continue to hinder the progress of science. It is well known that this country has more large telescopes than all the rest of the world combined, and yet our contributions to science have been relatively meager, and almost wholly of an observational character. We have indeed produced a number of excellent observers, because no great mathematical training is required for such work, but we have developed precious few eminent mathematical astronomers and even these have been less honored at home than abroad. For example, how many of the readers of this journal know anything of the great work of Dr. G. W. Hill, who is regarded in Europe as the greatest mathematical astronomer whom our country has yet produced? How many have even heard of the name of this great successor of Newton and Laplace, whose work in time to come will be ranked on a level with that of Hansen and Gauss, Adams and Leverrier? We think that all will agree that it is very unbecoming to the dignity of American science that so great a man shall live in our midst and by his labors do honor to America, while not only his work, but even his name, is less familiar here than it is in London and Paris, Berlin and St. Petersburg. The public seems to have labored under the impression that nothing is required for the cultivation of astronomy but a big telescope, the astronomer at the little end of the instrument never being for a moment considered. The idea is that with a big telescope one can look through and "see" the heavenly bodies! Is it not necessary to have a mind capable of interpreting what is "seen"? Does it ever occur to those persons who endeavor to advance science by building large telescopes and observatories that in order to do scientific work of the highest order something is required besides a big glass? We need a Struve, a Bessel or a Gauss at the little end of the telescope; we need a Laplace, a Leverrier or a Hill to discuss the observations obtained. But unfortunately too often no adequate provision is made for running our observatories, for maintaining a force of skilled astronomers sufficient to get the best results from the work of research that could be undertaken.

The result is that most of our observatories are doing about one-half or one-third of the work they could do if adequately supported. On the other hand a few observatories have abundant means, and yet for some reason little or nothing is done for the cultivation of exact astronomy, or for the reduction of observational material which has accumulated. These and other unfortunate circumstances have brought about the present peculiar condition of American astronomy, which authorities like Gould and Chandler recognize as positively deplorable.

The neglect of astronomical teaching and the placing of the centre of gravity of astronomical effort almost wholly in observational and photographic work has undoubtedly had much to do with bringing about the present state of affairs. One is sometimes led to believe that lecturing to students at a university or college is regarded as beneath the dignity of an astronomer; work of instruction is low drudgery compared to the accumulation of observational material! When did this change in the policy of astronomers come about? When did the education of astronomers become a matter of such small importance as to be unworthy of the attention of a great Observatory?

M. Tisserand, the illustrious director of the National Observatory at Paris, does not regard it as beneath his dignity to lecture at the Sorbonne; Gyldèn condescends to lecture at Stockholm, and Darwin and Newcomb and Hill do not regard it as useless drudgery. The same view was taken by Bowditch and Chauvenet, Watson and Peirce; and in short by all those astronomers who in the past have made whatever is excellent in the history of American astronomy.

The difficulties which confront astronomy at this time may not be insurmountable, but those who are acquainted with the facts and are interested in the science of their country will probably agree that the situation demands the earnest attention of all American astronomers. Some one has pointed out that the need of this country is not more observatories, but more astronomers and better management of the observatories we now have. If money is to be given for astronomical purposes, it would be better to give it for mathematical research in astronomy, and for the education of astronomers, than for any Observatory however vast and imposing. The accumulation of observations is of no value unless something can be made of them, and astronomical libraries are full to overflowing of observations which have never been utilized. It is of the highest importance that when we are building observatories we should remember, if they

are of any use, that skilled and trained astronomers are necessary; and that a more serious effort for the education of astronomers is demanded by a country full of observatories which are idle half of the time, or mismanaged.

We need Struves, Bessels and Herschels at the little end of the telescopes, we need Laplaces, Airys and Newcombs to discuss our observations; and although it may not be within our power to bring about these results, yet in order that whatever is possible may be done, all astronomers who have any regard for the future of American science should unite in a steadfast effort to improve the opportunities offered to students of astronomy and to encourage the cultivation of physical astronomy, which "by the dignity of its object and the perfection of its theories is now and must always remain the most beautiful monument of the human mind and the most noble title of its intelligence."

THE UNIVERSITY OF CHICAGO,
1895, Feb. 7.

A NEW DETERMINATION OF THE SATURNIAN BALL AND RING SYSTEM WITH THE GREAT LICK TELESCOPE.

E. E. BARNARD.

FOR POPULAR ASTRONOMY.

During 1894 one of the objects to which I devoted my time with the 36-inch equatorial was the planet Saturn. With the micrometer of the great telescope I made a complete redetermination of the entire Ball and Ring system of this planet.

I have thought a brief statement of the result of this work would be of interest to the readers of POPULAR ASTRONOMY.

A complete and detailed paper on the subject has been forwarded to the Royal Astronomical Society.

Besides the work of measuring the ball and rings, I also secured a series of measures of the diameter of Titan the largest of the Saturian satellites.

The magnifying power employed in the work was 520 diameters. For Titan 1000 diameters was used.

Following are the results of the measures extending from 1894, February 25, to 1894, July 2. These are all reduced to the mean distance of Saturn from the Sun:

	″
Outer diameter of the ring	40.294
Diameter center Cassini division	34.306
Width of Cassini division	0.558
Inner diameter outer ring	34.864
Outer diameter inner ring	33.748
Inner diameter inner ring	25.522
Inner diameter crape ring	21.033
Equatorial diameter of ball	17.744
Polar diameter of ball	16.307

The equatorial and polar diameters give for the compression or ellipticity of the ball

$$\frac{e-P}{e}=\frac{1}{11.44}$$

The measured diameter of Titan was

$$0.''588$$

These measures of the ball and rings differ from those of Hall with the 26-inch at Washington 1884-7 by small quantities only. The mean difference, having respect to signs, is $H-B=+\,0''.054$.

The above measures correspond to the following values in English miles:

Outer diameter of ring	172730	miles.
Width of Cassini division	2395	"
Inner diameter of outer ring	149620	"
Outer diameter of inner ring	144830	"
Inner diameter of inner ring	109530	"
Inner diameter of crape ring	90260	"
Equatorial diameter of ball	76150	"
Polar diameter of ball	69980	"
Diameter of Titan	2523	"

Careful measures were made to detect any excentricity of the ball with respect to the center of the rings.

Though it had previously been reported that the rings are excentric to the ball, the present series of measures show that at least during 1894 the ball was apparently in the exact center of the rings.

A statement was made many years ago by Struve that the rings were gradually and sensibly closing in on the ball.

The foundation for this theory was mainly due to an inspection of early drawings and measures of the rings previous to his day. The present measures with the 36-inch verify the work of Hall with the Washington 26-inch in completely disproving this idea since they accord with the best early measures in proving no measureable change has taken place since the time of Bradley.

There is considerable discrepancy in the early measures of the ball and the planet.

Herschel's measures about 1790 are singularly large. They are

indeed much further from the true values than those of any other observer of his day.

His measures are:

	″
Outer diameter of rings	46.677
Inner diameter outer ring	43.525
Outer diameter inner ring	42.234
Inner diameter inner ring	33.180
Equatorial diameter of ball	20.56

Following are some of the values obtained for the width of the Cassini division:

	″
Herschel 1792	0.645
F. Struve 1829	0.407
Bessel 1835	0.402
Decuppis and DeVico 1838	0.384
Encke 1838	0.775
O. Struve 1852	0.445
Jacob 1856	0.486
De La Rue 1856	0.940
W. C. Bond 1857	0.455
Mean	0.549

No abnormal features were seen on the planet or its rings.

The black and white spots recently reported with small telescopes were not seen at any time.

The inner portion of the crape ring was partially transparent. The ball of the planet could not be seen through this ring up to the edge of the bright ring. Showing that the crape ring becomes denser as it approaches the bright ring. This condition was first beautifully shown to exist at the eclipse of Japetus in the shadow of the crape ring 1889, Nov. 1. (See *Astronomy and Astro-Physics.*)

But one dark narrow belt was seen upon the planet, this was near the middle of the great light equatorial zone.

Mt. Hamilton, 1895, Feb. 1.

THE SPECTROSCOPE IN ASTRONOMY.

TAYLOR REED.

For Popular Astronomy.

A great part of our knowledge of the Sun has been gained by a study of the edge of the Sun's disc. Here the conditions are changed. On the disc proper we have the incandescent interior, with its matter in a solid or liquid state possibly, more probably gaseous under high pressure; this interior shines through an outer layer of cooler gaseous matter under low pressure, which

also may be incandescent. At the edge of the Sun's disc we see this gaseous matter alone with nothing brighter beyond it; and a shining gas gives a spectrum in which the lines are bright. Could the lines be seen thus bright or "reversed"? For hydrogen the answer was immediate: easily and always. For the other lines the reply is even yet in part uncertain.

The layer of hydrogen surrounding the Sun is of some depth; as seen at the edge of the Sun's disc wide enough at any point to be separately examined by the spectroscope. This "chromosphere" is 5,000 to 10,000 miles in depth, and the filaments of which it is composed are vertical. To be sure it can be seen for an instant at the time of a total eclipse. But if not absolutely it is still almost entirely a spectroscopic creation.

At times of total eclipse it has been observed that just as totality begins many lines turn suddenly, for a second or so, bright. The Moon in its progress before the Sun has at that moment cut off all the bright interior of the Sun, leaving visible only the cooler gaseous edge. Many lines are "reversed," as has been both observed and photographed. Are all reversed? Theory says they should be. Observation has not yet decided positively yes or no.

In an eclipse it is the Moon that cuts off the light of all the Sun but the edge, and so the obstruction is beyond our atmosphere. At ordinary times the slit plate of the spectroscope must be the screen, while the edge of the Sun alone must be in the narrow slit. But the Earth's atmosphere in its ceaseless moving churns the two parts of the image together; so that the observation such as is made at an eclipse of the edge alone with none of the interior, has probably never been accomplished. The most even suspected is that at one or two times of magnificent steadiness of air the lines have become as bright as the general spectrum; that is, the spectrum uniform, and this only a few times in the whole history of these observations.

But frequently there is found at the edge of the Sun's disc a point or small region of disturbance; of motion, as shown by displacement of lines, particularly of the hydrogen lines; or of pressure, as shown by thickening of lines. At such places lines are often seen "reversed;" sometimes many lines. Some lines are reversed only at the place of disturbance strictly. Lines of another class are reversed over a larger region, but still only near the point of disturbance; they seem to be half way between the other lines and the hydrogen lines. Of the second class some do not correspond with dark lines in the ordinary spectrum; per-

haps none do. Those of the first class seem surely to be the dark lines reversed. But the various lines even of the same chemical element perform very differently. In all about 300 lines of all kinds have been seen bright; a few easily, but a good half of them rarely, and very faintly, brightened.

Prominences extending out from the edge of the Sun were observed at total eclipses. Spectroscopists learned early that they could be observed at any time by placing the slit of the spectroscope at the edge of the Sun over the prominence and opening the slit. If a hydrogen line be observed, the form of the prominence is seen. The existence of a prominence at any point is known by the brightening of a hydrogen line away from the exact edge of the Sun. These prominences have long been the subject of study, as well as most easy and most pleasant, observation. Their study is pleasant from the countless variety of form they offer, and from their rapid change of form. And their study is easy because with very limited equipment they may be superbly shown; better usually than with the giant spectroscope of a great equatorial.

Of classes of prominences there are two, differing slightly in chemical nature, utterly in form, and much in attendant circumstances:—the quiescent, and the eruptive or metallic.

Quiescent prominences are well described as to form as having the shape of a banyan tree. A mass of matter some distance above the Sun is connected with the Sun by one or more stems. Not infrequently the stems are absent, and the prominence appears as a cloud, entirely detached from the Sun's surface. The markings on the prominence in any case are considerable, irregular and interesting. The change in appearance is sometimes so rapid as to be considerable in two or three minutes. Or, they will remain almost unchanged for hours. A change in form or size is not in general attended by motion toward or from us; in fact such motion is not usual in quiescent prominences. Chemically they consist of hydrogen and an unknown and mysterious substance to which the name "helium" has been assigned. Their height varies from 10,000 to 150,000 miles; 30,000 being perhaps an average height. Their width is usually greater than their height.

The eruptive prominences are usually very small; most of them but a few thousand miles in height. When high they always take the shape of spikes or horns. The highest of them are far and away the highest of all prominences. The highest ever observed extended 400,000 miles from the Sun's surface, a distance equal

to a whole radius of the Sun. They are called "eruptive" because violent motion usually accompanies them; particularly at the base of the prominence, as if there were an eruption. They are called "metallic," because some metallic lines are reversed at least at the bottom of the prominence, and occasionally for some distance above the Sun's surface. Most eruptive prominences occur near sunspots; especially near young sun-spot groups. Unlike the quiescent prominences they show a decided preference for the sun-spot zones.

In the spectrum of the Sun's corona the one pre-eminent thing is a bright line in the green. The lines of hydrogen appear faintly as bright lines, and a number of lines in the extreme violet and ultra-violet. A faint continuous spectrum is shown, which may not be uniform in brightness throughout the spectrum. The spectroscope thus demonstrates, by showing these bright lines, that the incandescent matter of the corona is in the gaseous state; and that in it hydrogen plays a secondary part. The early observations indicated that this prominent bright line due to the corona coincided with a well-known line of iron; leading to the incredible result that the inconceivably rare corona was in some way due to heavy vapor of iron. But greater spectroscopic power showed that the line in question is double; and that one component is the iron line, the other that of the corona. Of what element is the corona then composed? In despair the answer is given of "coronium."

To our little knowledge of the corona the spectroscope thus contributes its mite; but still leaves it the Sun's mystery. An analogy cannot fail to occur to the mind. The Earth has its similar mystery, in the phenomenon of the aurora. Both exist above the surface where any gas is very rare. Both have their beautiful streams. Each has a characteristic form in the neighborhood of the pole of its sphere. Apply the spectroscope to both and the analogy is continued. Each gives in the spectrum an unidentified bright line, with fainter companions. Each shows a faint continuous spectrum.

At the present time work with the spectroscope on the Sun continues active. In fact work on the Sun, and spectroscopic work on the Sun, are synonymous terms; identical terms, except for important researches on the Sun's heat, and some minor observations on spots. If the volume of information the spectroscope has given us of the Sun is large, we cannot suppose it will be no larger. For if there is hope of advance in knowledge of the Sun it seems to lie in the spectroscope, and in the bolometer.

ASTRONOMICAL EPHEMERIDES.

J. MORRISON, PH. D.

FOR POPULAR ASTRONOMY.

In ancient and mediaeval times the astronomical ephemerides were of the simplest and rudest kind. Founded on the false system of Ptolemy and more or less interwoven with astrology, they contained little more than the dates of the entrance of the Sun, Moon, and planets into the zodiacal signs, the rising and setting of the Sun and Moon and the eclipses. These rude predictions served the purposes of daily life in those days, and it is a remarkable fact that some features of these astrological ephemerides, as they may be called, have survived even to our own day, for many of the almanacs still prepared for the use of our rural population, depict on their title page the signs of the zodiac and the effects which are supposed to follow the passage of the Sun or Moon from sign to sign. These are now the only traces left of those ancient ephemerides. From these circumstances it is popularly believed that astronomy took its rise or had its origin in astrology, but the testimony of all ages, goes to show that the genuine astronomers never entertained any belief in Astrology. The only instance on record so far as I can learn, is that of the celebrated Kepler who published an almanac or ephemeris which, unfortunately for his reputation, consisted largely of astrological predictions. It is claimed however that Kepler was forced to do this by reason of the straitened financial circumstances in which he was placed, his income being quite inadequate for his support. As the motions of heavenly bodies became better known, the almanacs published from time to time by private individuals, increased in volume, usefulness and accuracy, but it was not until after the discovery of the law of universal gravitation and the invention of the Differential and Integral Calculus by Sir Isaac Newton, that the computation of a tolerably accurate ephemeris became possible. Newton's researches enabled his successors to prepare tables from which the places of the Sun, Moon and planets could be computed with great accuracy. The first regular annual ephemeris constructed on strictly scientific data, dates from this period and was issued in 1679 by Picard of France under the name of the "Connaissance des Temps" and has continued without a single interruption to the present day. As might be expected the first few numbers were small and imperfect. It was soon improved however by the assistance of the astronomers of the French Academy and issued under the auspices of the Govern-

ment. It contained not only useful predictions of Astronomical phenomena from the tables then in use, but also astronomical observations made at Paris and elsewhere. On the creation of the Bureau of Longitude in 1795, the preparation of the work was entrusted to it and has remained under its charge ever since. This is the oldest, and, as to number of pages, the largest ephemeris ever published; it contains nearly 800 pages, the last hundred being taken up with Geographical positions for the use of Navigators.

Great Britain being the leading maritime nation of the world, was of course naturally interested in the discovery of any method which would furnish the longitude at sea and accordingly offered a reward of ten thousand pounds to any one who would devise any practical and sufficiently accurate way of determining the Greenwich time on board a ship to within two minutes, after having been six months at sea.

This condition was very exacting and has never been attained. The method then devised and still used to a very limited extent, was the well known one of lunar distances, which however cannot be relied on to within at least four minutes. The modern method of determining longitude at sea, even on long voyages, by means of chronometers, has almost completely superseded that of lunar distances.

The British Nautical Almanac was first issued for the year 1767 to supply as far as practicable the wants of navigators and in order to carry out this object the Astronomer Royal was charged with the duty of preparing such Tables of the motion of the celestial bodies as would facilitate the determination of the longitude. The method of lunar distances was found to be quite adequate to the purpose, but it required an ephemeris of the Moon and the position of certain fixed stars situated near the Moon's path. The tables for supplying the former were prepared by Tobias Mayer of Gottingen, assisted by the celebrated Euler who prepared the formulæ for the construction of the Tables, and the Almanac was regularly issued three years in advance under the direction of the Astronomer Royal—the Rev'd Dr. Maskelyne. Three thousand pounds of the reward were given to the widow of Meyer and the same amount to Euler for his services.

During the first half century of its existence the astronomical data were rather meagre and confined to such as were absolutely necessary for the determination of positions. Under the direction of a committee appointed by the Lords Commissioners of the Admiralty in 1830, to consider the subject of improving the Nautical

Almanac, a radical change was made in the work which was first carried out in the almanac of 1834. Additions and improvements have been made from time to time since, and it is to-day the best and most accurate work of the kind all the principal portions being computed in duplicate. The Spanish Nautical Almanac has been issued continuously since the beginning of the present century, has also been enlarged and improved recently and now has about the same number of pages as the British, but contains less matter on a page. The data in it are not as well arranged or as complete as in the British Almanac.

Germany publishes two works of this class, one the "Berliner Astronomisches Jahrbuch" purely astronomical and designed for the use of astronomers only; the other the "Nautisches Jahrbuch" purely nautical and intended solely for the use of navigators. The latter is somewhat similar to the American Nautical Almanac but by no means equal to it as regards completeness or arrangement.

The Italian ephemeris is published by the Milan Observatory, and has entered on the second century of its existence. It is designed chiefly for astronomers and is largely taken up with astronomical observations of the planets, comets, etc. The Portuguese Nautical Almanac is adapted to the meridian of the University or Observatory of Coimbra and possesses some peculiarities not found in other almanacs of this class. The Sun's R. A. is expressed in arc and not in time; the positions of the fixed stars are omitted; the lunar distances are given for intervals of twelve hours and not for three as in other almanacs, but what is utterly useless both to the astronomer and navigator, is the time when the Moon enters the signs of the zodiac. Perhaps this information is intended for the use of the rural population who may be to some extent guided thereby in their agricultural operations. It is the only trace of astrology to be found to-day in any almanac or ephemeris of any scientific pretensions. The Russians use the British Almanac with the explanations and headings printed in the Russian language. Sweden and Norway use the British Almanac, so also do Denmark, Holland and Belgium.

The American Ephemeris and Nautical Almanac with which we are more directly interested, was commenced in 1849 and issued in 1855 under the superintendency of the late Admiral C. H. Davis, with the late Professor Pierce as consulting astronomer. It possesses some new features and contains more useful matter than any other. It is divided into three parts; the first for the use of navigators as well as astronomers is adapted to the

meridian of Greenwich; the second for astronomers only is adapted to the meridian of Washington and the third also adapted to the meridian of Washington, consists of phenomena to be observed—an exception however being made in the case of eclipses of the Sun and Moon, which are given in Greenwich time, since they are phenomena which belong to the whole world in general.

The first part gives the position of the celestial bodies at equal intervals of time, viz: Greenwich mean noon, this being the most convenient epoch for both the navigator and the astronomer. The second part gives the positions not at equi-distant intervals but at their transit over the meridian of Washington and also data for computing the approximate date of transit over any other meridian near Washington. The third part contains a great deal of matter for the practical astronomer which is not found in any other similar work—such as ephemerides and diagrams of the satellites of Mars, Saturn, Uranus and Neptune and other interesting phenomena. In this connection it will not be out of place to refer very briefly to some of the tables and theories from which astronomical ephemerides are computed. Under the theory of Ptolemy no advance could be made towards the construction of astronomical tables which would even approximately give the position of any of the heavenly bodies. After the discovery of the true system by Copernicus, Kepler made the first step in this direction by the discovery of the three celebrated laws that bear his name. When it was known that each planet described an ellipse with the Sun in one of the foci, it became possible to form tables of the motion of these bodies much more accurate than those used before. Kepler also showed how to pass from the mean to the true anomaly by computing the '*equation of the centre*' by far the largest inequality in elliptic motion, and the famous *Kepler problem* is still one of the difficulties with which the amateur astronomer has to wrestle. Such tables were published by Kepler in 1632 under the auspices of the Emperor Rudolph and hence called the Rudolphian Tables; but without the knowledge of the theory of gravitation it was not possible to advance any farther. Newton was the first to prove that a body such as a planet, subject only to the action of a central body like the Sun would move strictly in accordance with Kepler's laws. This he did in the first proposition of his celebrated Principia and no one who reads it can fail to be struck with the marvellous simplicity of the demonstration and the prodigious results that flow from it. By the theory of gravitation each planet must disturb

the motion of the others and cause them to deviate slightly from true elliptic motion. The calculation of the mutual action of the planets in changing the form of their orbits, is a problem of prodigious difficulty—one of the most difficult that human genius ever encountered, but the solution was absolutely impossible by the geometrical process employed by Newton. It must not however, be forgotten that he invented the Calculus and rendered it possible for his successors to complete what he left unfinished. To the writings of La Grange, La Place, Euler, Hansen, Bessel, Le Verrier and other continental mathematicians we must refer for a full development of the subject. A complete and rigorous solution of the problem is not possible, that is to say, it is impossible to find an absolutely definite mathematical expression for any coördinate of a planet. The solution always comes out in the form of an infinite series of terms proceeding in ascending powers of the eccentricities, mutual inclination and mean anomalies, each term being in general a little smaller than the preceding one. By increasing the number of terms we can approach as near as we please to the truth but can never reach it; we are content, however, to stop when the neglected terms are beyond the limits of observation. This problem has engaged the attention of the ablest mathematicians and astronomers during the last two centuries and many improvements have been introduced from time to time but no general method is applicable to all cases, one method being applicable only to the Moon, another to the superior planets, another to the inferior planets and so on. The work has been done for the most part by individual mathematicians—thus Hansen spent the greater part of his life in these investigations, and his tables of the Moon are now the only ones used for computing the Moon's place in all the astronomical ephemerides of the world, and the celebrated French mathematician, Delauney, spent over fifteen years of continuous labor on his great work on the motion of the Moon. Under these circumstances it is not at all surprising that the astronomical tables are not as accurate as the present state of the science demands.

The only systematic tables for all the large planets are those of LeVerrier, completed just before his death. His tables are used in computing the Ephemerides of the Sun and planets for the English, French, German and Spanish Nautical Almanacs and are the most accurate now in use. There are several other tables of the Sun, Moon and planets which deserve a passing notice. About the beginning of the present century Baron De Zach's solar and lunar tables appeared and shortly after Burg's lunar and Delam-

bre's solar tables, all of which are now obsolete and mere matters of history. Burkhardt's lunar tables appeared in 1812 and were used for a long time in the British and French Nautical Almanacs until superseded by Hansen's already alluded to. Pierce's lunar tables were prepared for the use of the American Ephemeris and Nautical Almanac and were so used up to 1882 inclusive, when Hansen's tables were adopted. The only tables of the Sun now in use are those of Le Verrier and Hansen, the former used by the British and the latter by the American Nautical Almanac. For the planets the old tables of Lindenau and Bouvard, the former published in 1810 and the latter in 1821, are still employed in the American Ephemeris for Mars, Jupiter and Saturn while the British use the more recent and accurate tables of Le Verrier. For Mercury, the American Almanac uses Winlock's tables constructed from formulae published by Le Verrier in 1846; they are now deviating from the true place of the planet and hence are not as accurate as the new tables of Le Verrier published several years later. Hill's tables of Venus published in 1872 are simply a revision of Le Verrier's tables of the same planet and substantially identical with them. Experience has shown that no set of tables hitherto constructed can be depended on for more than half a century. Even Hansen's tables of Moon are now deviating considerably from the true place and therefore require corrections.

From the preceding brief history of Ephemerides, it is quite evident that the preparation of all the tables and other data necessary for the construction of an Ephemeris or Nautical Almanac, is a work of enormous labor and of prodigious difficulty, and requires for its execution the keenest analytical powers and a sound and profound knowledge of the higher mathematics, the great instrument of all exact inquiry without which no one can form an independent opinion on any subject which properly falls within its range.

In the following series of articles it is proposed to explain the use and construction of an Ephemeris and to give a demonstration of all the necessary formula employed for this purpose.

To each article will be added a few practical and useful astronomical problems for students and amateurs who may wish to apply their knowledge of mathematics to the study of the grandest and noblest of the physical sciences.

The next paper will be devoted to the explanation and computation of the ephemeris of the Sun as contained in the American Ephemeris and Nautical Almanac.

WASHINGTON, D. C., Feb., 1895.

NOVA AURIGÆ.

E. E. BARNARD.

FOR POPULAR ASTRONOMY.

The remarkable new star which burst forth in the constellation of the Waggoner in December of 1891 and which was discovered by Dr. Anderson on February 1, 1892, is still visible as a small star and has not changed in physical appearance since the fall of 1892.

When this object was first announced in February, 1892, Mr. Burnham made a careful and accurate chart of the neighborhood of the Nova with the 36-inch refractor of this Observatory. He measured the positions of some thirteen stars in connection with the Nova. His very complete and valuable paper on these measures was published in the *Monthly Notices* of the Royal Astronomical Society in April, 1892, Vol. LII, pp. 433-437.

Mr. Burnham severed his connection with this Observatory in 1892 before the Nova had again come into position for measurement. When the star came around again I took up the work of following it with the filar micrometer of the 36-inch in hopes of detecting motion or parallax to the object.

These measures have been kept up to the present time and have resulted in showing that the Nova has remained perfectly fixed with reference to the comparison-stars. The measures have failed to show any evidences of parallactic displacement so that the star must be at an enormous distance from us. (See *Astr. Nach.*, 3238.)

The fixity of the Nova will be at once apparent upon comparing the yearly means of my measures of its position with reference to the neighboring stars E and F of Mr. Burnham's measures. According to Mr. Burnham the magnitudes of these comparison-stars are:

$$E = 11.7^m. \qquad F = 10.4^m.$$

Following are the yearly means of my measures of position-angle and distance. A is the Nova:

A AND E.

Year.	Pos. Ang.	Dist.	
	°	″	
1892.860	323.38	74.58	(16 nights' measures).
1893.905	323.43	74.51	(14 " ").
1894.918	323.41	74.66	(3 " ").

A AND F.

1892.863	32.63	84.94	(18 nights' measures).
1893.831	32.89	84.91	(8 " ").
1894.918	32.63	84.94	(3 " ").

These are in very satisfactory accord and show that no change of position has taken place during the interval covered by the observations.

This result, to say the least, is surprising when one considers the enormous motion assigned to this object by spectroscopic observations in the line of sight.

At my last observation of the Nova, on Dec. 31, 1894, I estimated its magnitude to be 10.5 on the scale used by Mr. Burnham in his double-star work.

According to the observations made by Mr. Burnham in the spring of 1892, this star was, when brightest, between the 5th and 6th magnitudes. It remained nearly constant in its light until about the 9th of March, 1892, when it began steadily to decrease in magnitude, and by the first of May had about reached the limit of the great telescope. It brightened up again some four months later to between the 10th and 11th magnitude at which brightness it has remained essentially constant since. At the second brightening up the object seemed to have become transformed into a small nebula or nebulous star—though this change has been doubted by some astronomers.

MT. HAMILTON, Cal., 1895, Jan. 1.

THE ASTRONOMICAL PROGRAM FOR 1895.

C. A. YOUNG.

FROM THE COSMOPOLITAN:

The astronomical program of the year, so far as it is a matter of prediction, offers nothing of exceptional rarity or interest.

The number of eclipses is somewhat larger than usual, but three of the five are only small partial eclipses of the Sun, and are all invisible in the United States. The two eclipses of the Moon, however, which occur on March 10th and September 3d, are both total, and are both visible in this country from beginning to end. The first of them is also observable in Europe, and will therefore afford an opportunity for coöperative observations of the occultations of small stars that lie in the Moon's path while it is obscured—observations which are of great value in de-

termining the distance of the Moon and the form and size of the Earth. This year, also, the Moon every month passes over the Pleiades, and their occultations possess the same value if observed at widely separated stations.

The sunspot maximum was reached two years ago, and the activity of the solar surface is now declining, so that there is no reason to look for any phenomena of special interest in that quarter for the present.

As for the planets, Mars is already far away, and for more than a dozen years will not again be as favorably situated as he was last autumn. Saturn is far to the south, and even at his opposition in April and May will be too low down for satisfactory observation. During the first three months of the year Jupiter, on the other hand, will be admirably placed and will monopolize the interest of observers; and during the spring and summer Venus will be splendid in the evening sky.

The only periodic comets whose return is due this year are Encke's and Brorsen's. The former which completes its orbit every three and a third years (the shortest comet-period known), came in sight early last November, but does not reach its perihelion until February, and is still under observation. It is very faint, seldom becoming visible to the naked eye, and the chief interest that attaches to it lies in the strange continual shortening of its period, a phenomenon which still remains without any certain explanation, though very generally supposed to be due to its collision with some invisible meteoric swarm. Brorsen's comet which made its last visit in 1890, and has a period of five and a half years, is due again next summer; but it is unfavorably situated, and will be so faint that it may very possibly elude observation.

Of course, it is perfectly possible, and much to be desired, that some great comet may appear entirely unannounced, or that some "new star" may unexpectedly burst into brilliancy; but such phenomena do not come within the range of our prediction.

Probably before the close of the year the immense forty-inch telescope of the Chicago University will be erected in the magnificent observatory now building for it at Lake Geneva, Wisconsin; and it is possible that by that time the great instrument now being constructed for the Observatory of the Cape of Good Hope may also be mounted, so that hereafter the southern hemisphere may possess at least one instrument comparable in power with those that are now so numerous in the northern. And yet, after all, the real progress of astronomy depends more upon the unob-

trusive, faithful, laborious work of the mathematicians and routine observers than upon big telescopes and sensational discoveries.

PROGRESS OF ASTRONOMICAL PHOTOGRAPHY.

H. C. RUSSELL, F. R. S.*

Rutherfurd† began his work in lunar photography in 1858 with an equatorial 11¼ in. aperture and 14 ft. focal length. Finding it impossible to get with this instrument, intended for vision, such perfect photographs as he desired, he tried first a reflector of 13 in. but ultimately gave it up, and determined to make an 11¼ in. objective corrected for photographic purposes. This was not accomplished until December, 1864, and he did not get a satisfactory negative until March 6th, 1865. The construction of this lens was difficult, because its progress could not be tested by the visual image. Mr. Rutherfurd got over the difficulty by testing it with a spectroscope. With this instrument stars down to the ninth magnitude were taken with three minutes' exposure, and the only photograph of the Moon taken with it was sharper than any other Mr. Rutherfurd had ever seen.

It was suggested at the time that photographs of the sky 2° on a side might be taken with it.‡

The power to obtain photographs of stars down to the ninth magnitude with such a small aperture and an exposure of three minutes, promises to develop and increase the application of photography to the mapping of the heavens, and in some measure to realize the hopes that have so long been deferred and disappointed.

On January 11th, 1869, M. Janssen§ presented to the Academie of Sciences a short note pointing out that it was possible to isolate any part of a spectrum by placing a second slit near the eyepiece—an idea which underlies some of the most remarkable results of the present day, but it lay dormant until 1892.

In 1871 Dr. Draper‖ completed a 28 in. silvered-glass reflector, made for the purpose of photographing star spectra, and in May,

*Government Astronomer at Sidney, Australia. Extract from a recent address. Continued from page 176.

† An investigation into Stellar Photography, by E. C. Pickering, p. 181; also Astronomical Register, Vol. II, p. 109. A list of Rutherfurd's photographs is given in the Smithsonian Miscellaneous Collections, No. 311, p. 89.

‡ Quarterly Journal of Science, 1865, pp. 651 and 652.

§ Comptes Rendus, 1869; also British Association Report, 1869, p. 25.

‖ Nature, Vol. XXI., p. 23; also Astronomy and Astro-Physics, June, 1893.

1872, and again in August, he photographed the spectrum of Vega, showing four strong lines. Dr. Huggins, as we have seen, photographed the spectrum of Sirius on a collodion plate in 1863. In 1870* Professor C. A. Young succeeded in photographing the prominences of the Sun. Negatives were made showing the solar disc on a scale 2 in. in diameter, which represented clearly the general form of the prominences, but the telescope was too small for good definition, and the work was given up. The light of the hydrogen line Y was used because more actinic than K. They were taken with an open slit on the spectroscope.

In 1872 Mr. Ellery photographed the Moon with the great reflector at Melbourne with marked success, and produced the finest photographs that had been seen up to that time.

In 1873-4 many persons urged that photography should be applied to the transit of Venus, and Sir G. B. Airy, after some hesitation, adopted this as an auxiliary method, and in 1874 it was used by the majority of parties sent out as a means of determining the position of Venus on the Sun. It did not prove so successful as it was hoped it would, but on many of the photographs taken in New South Wales the ring of light surrounding the planet at and near the Sun's limb was clearly recorded and shown to be brighter than the Sun itself by the greater deposit of silver which it produced. In 1874, Dr. Huggins tried to photograph the spectra of planetary nebulæ, but without success, the instrument at his command not being large enough.

The year 1876 was an important epoch in the application of photography to the astronomer's needs, for in that year gelatine dry plates, which had been first put on the market in 1871, attained such perfection that Dr. Huggins, after an extensive series of tests comparing them with the best collodion films, gave the preference to the new-fashioned dry plates, and therefore exposures could be continued for hours and even days instead of a few minutes, the possible limit for collodion plates. Dr. Huggins used the new plates to record the spectrum of Vega on Dec. 21st that year; it contained seven strong lines, all of them strongly shaded at the sides, and two of them coinciding with the well-known lines of hydrogen. Thus another advance was made; the greatest number of lines previously photographed was four.

Dr. H. Draper† in 1877 announced his discovery of oxygen in the Sun in a paper read before the American Philosophical Society. On July 20th he found by photographing the spectrum a number

* Nature, Vol. III., p. 111.
† Nature. Vol. XVI., p. 364.

of bright lines in the solar spectrum coinciding with the bright lines of oxygen and said, "We can no longer regard the solar spectrum as a continuous spectrum with certain rays absorbed by a layer of ignited metallic vapors, but as having also bright lines and bands superposed on the background of the spectrum."

In 1877 came another important advance. M. Janssen succeeded* in photographing the Sun, with extraordinary results. The images were 12 in. in diameter, and displayed remarkably sharp details of the sunspots, willow leaves, rice grains, and faculæ. But the most remarkable result obtained—and which was exclusively due to the improved photographic method—the whole photosphere was covered with a fine granulation of very varied forms, dimensions, and arrangements; but the most remarkable of all was the discovery of a fine photospheric network —"Reseau photospherique." The forms generally have rounded contours, but some are rectilinear and others polygonal; and in the intervals of this network the rice grains are distributed and definitely bounded, and in their interior (*i. e.*, the net spaces) the "granules are half obliterated, drawn out, and confused." This great step in advance was obtained cheifly by improving the old flashing shutter and reducing the time of exposure to $\frac{1}{3000}$th part of a second.

In 1878† Dr. H. Draper succeeded in getting very perfect photographs of the solar eclipse in July of that year, showing that the spectrum of the corona was similar to that of the Sun—in other words, the corona must be sunlight reflected from matter in the neighborhood of the Sun, and, if that accounts for the whole of its light, then it would not be possible to photograph it apart from the Sun. The photograph was confirmed by the visual observations of Professors Barker and Morton, two of Dr. Draper's party.

In a paper read before the Royal Society on Dec. 18th, 1879, Dr. Huggins gives the details of his work in photographing star spectra since he began his new and successful process in 1876, when he obtained seven lines in the photograph of the spectrum of Vega. He used a prism of Iceland spar and lenses of quartz. With this arrangement definition was so good that he could count seven lines between H and K in the solar spectrum, and could photograph star spectra from G to O in the ultra violet. He made it a practice to set the slit always to the same width ($\frac{1}{350}$ of an inch) and he used gelatine dry plates because they were more sensitive

* Nature, Vol. XVIII., p. 643.
† Nature, Vol. XVIII., p. 43.

and could be exposed as long as he desired.* He had photographed the spectra of Sirius, Vega, Arcturus, Beta Pegasi, Betelgeux, Capella, Alpha Hercules, Rigel, and Alpha Pegasi; also Jupiter, Venus, Mars, and portions of the moon. The planetary spectra show no sensible modification in the violet and ultra violet parts such as would result from atmosphere on any of them. Six of the stars belonged to the "white" class. In this paper Dr. Huggins states that the spectroscope aided by photography might be made to afford valuable information in the study of variable stars—a prophecy which we shall find was fulfilled a few years later—and that it was evident the period of the Sun's rotation could be determined by spectroscopic observation on each side of it. These brilliant results had not been attained without a determined battle with the difficulties in instruments and appliances then in use, and an amount of energy had to be expended in that way that would have borne grand fruit had instrument makers been equal to the demand of science. An indication of what had to be gone through is found in the fact that, in order to get the equatorial to follow the stars, it had been necessary to get made no less† than seven different driving clocks.

In July, 1881, Professor Vogel‡ announced his important work and complete success in photographing the spectra of rarefied hydrogen, which gave a spectrum almost exactly coinciding with Dr. Huggins' ultra violet spectra of white stars.

Dr. H. Draper,§ on March 11th, 1881, photographed the nebula in Orion, and one of the stars shown in it is of 14.7 magnitude, which is about the limit of what can be seen with a telescope of that size. So he had just brought the star camera to record as much as could be seen, and he would doubtless, had he lived a few years more, have done what has since been done, viz., photographed stars far beyond the range of vision: it was done soon after his death by A. A. Common and others.

Between 1868 and 1881 improvement in spectra photographing apparatus had been very great, but there had in the interval been no comet bright enough to try the experiment of photographing its spectrum, and Dr. Huggins‖ eagerly seized the opportunity on the 24th of June, and succeeded in getting a fine photograph of the spectrum of bright comet *b* of 1881. The photograph was the result of an exposure of one hour, and on another bright night he

* Nature, Vol. XXI., pp. 269 and 270.
† Nature, Vol. XXXI., p. 84.
‡ Nature, Vol. XXI., p. 410.
§ Nature, Vol. XXIV., p. 308; also An Investigation into Stellar Parallax, by E. C. Pickering, p. 181.
‖ British Association Report, 1881, p. 520, with plate; also Nature, Vol. XXIV., p. 464.

got one with one and a half hour's exposure. Two superposed spectra are shown—one a continuous spectrum of reflected sunlight extending from F to a little beyond H; the other two sets of bright lines from the comet's own light, with a suspicion of the presence of a third set of lines.

Dr. Henry Draper* succeeded in photographing the comet *b* in Aurigæ on June 24th, 1881, in one exposure of two hours forty-two minutes; the comet is shown with a tail about 10° long, and several stars showing through it. He tried to get its spectrum first, with a direct vision spectroscope and an exposure of eighty-three minutes, which gave a spectrum of nucleus, coma and tail, then used a two-prism spectroscope, with three exposures, 180, 196, and 228 minutes. There is in the spectrum a heavy band above H, which is divisible into lines between G and *h*, and another between *h* and H.

M. Janssen† also secured a photograph of comet *b* on July 1881. He used a telescope half a metre in aperture and 1.60m. in focal length. The photograph was exposed for thirty minutes, and shows a tail 2½° long, in which were some rectilinear rays, which were revealed by the camera, but not visible. It will be remembered that, seven days before, Dr. H. Draper, using a larger telescope and more than five times the exposure, found the tail on his photograph 10° long.

On the 7th of March, 1882, Dr. Huggins‡ succeeded in taking a photograph of the spectrum of the great nebulæ in Orion. He used the 18-in. reflector metallic speculum, and the exposure was limited by clouds to forty-five minutes. The photograph shows a spectrum extending from a little below F to beyond M in the ultra violet; there are five bright lines as well as a narrower continuous spectrum, which Dr. Huggins thought was due to stellar light. It may be mentioned that only four bright lines had been seen by the eye.

Dr. Draper§, of New York, had been for eighteen months taking photographs of the nebula in Orion—to see, first, if it was changing, and, second, for the spectra of the various parts. In March, 1882, he made two good photographs with two hours' exposure. On these he saw four of Dr. Huggins' lines, but not the fifth (λ 3730). In one of the plates is the spectrum of a tenth-magnitude star—the smallest star that had so far had its spectrum photographed.

* Nature, Vol. XXIV., pp. 236 and 308.
† Nature, Vol. XXV., p. 132.
‡ Nature, Vol. XXV., p. 489.
§ Nature, Vol. XXVI., p. 33.

On May 31st, 1882, Dr. Huggins* obtained a photograph of the spectrum of comet (Wells). It showed an essential difference between the spectrum of this comet and others. The nucleus shows a distinct spectrum, in which five brighter parts are seen, probably due to bright lines. The spectrum extends from F to a little beyond H, and no Fraunhofer lines can be seen in it.

Professor Schuster's photographs of the eclipse of May 17th, 1882, show the coronal light is very strong from about G to H; and Dr. Huggins† thought that it would be possible, by using absorbing media, to keep out the other rays, and that it would be possible to photograph the corona by the part between G and H. The importance of this will be seen when it is remembered that the eclipsed sun is only visible about eight days in a century, and then only from small and inconvenient areas of the Earth's surface, and even this small chance is again limited by cloud and possibly inaccessible positions on the Earth's surface. The possibility of making an artificial eclipse such that the Sun's surroundings could be photographed at any time was a problem worth working at, and Dr. Huggins,‡ with characteristic energy, threw himself into it, and succeeded by using absorbing media in getting faint but unmistakable photographs of the corona; the available media were insufficient for better results.

In 1866 and 1868§ he had tried by the same method to see the prominences, but met with only partial success for want of more suitable media. He had, however, in 1867,‖ by means of absorbing media, insulated the spectra of different parts of the Sun's surface, such as the spots and the *umbræ* of spots. The photographs of the corona taken by Dr. Huggins about the time of the eclipse of May 17th, 1868, were examined by Captain Abney, who said that "not only were the general features in them the same as in those taken by himself in the actual eclipse in Egypt, but also that details, such as rifts and streamers, have the same form and position," but the absorbing media were not satisfactory, and he subsequently used a reflecting telescope and chloride¶ of silver as a sensitive surface, which is sensitive only to violet rays. With this some success was attained, but not enough to satisfy Dr. Huggins, and the work was given up, although he felt "that problems of the highest interest in the physics of the Sun

* Nature, Vol. XXVI., p. 179.
† Nature, Vol. XXVII., p. 199,
‡ Nature, Vol. XXVII., p. 199.
§ Royal Astronomical Society, Monthly Notices, XXVIII., p. 88, and XXIX., p. 4.
‖ Royal Astronomical Society, Monthly Notices, Vol. XXVIII., p. 88.
¶ Nature, Vol. XXVIII., p. 606.

are doubtless connected with the varying forms of coronal light, which only seem to admit of solution on the condition of its being possible to study the corona continuously." From fifty photographs of the corona which Dr. Huggins had taken in this way during May, Mr. Wesley was able to prepare a number of drawings of the corona.

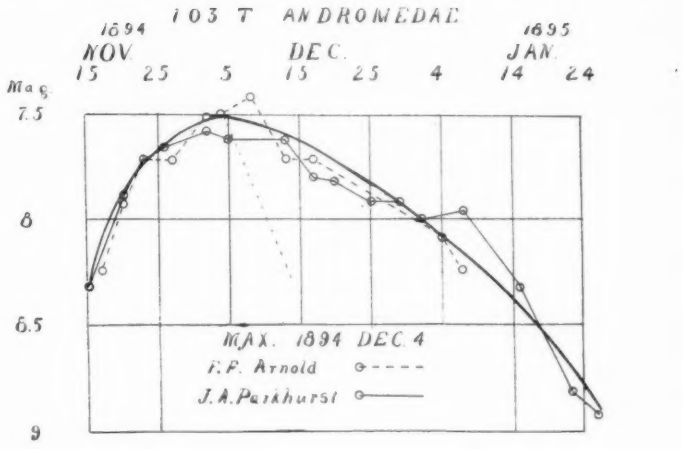
LONG PERIOD VARIABLES.

J. A. PARKHURST.

For Popular Astronomy.

I give below the observing lists of four of the regular observers of variables. Mr. Dearden's list is incomplete and Mr. Arnold's is necessarily short on account of a lack of a fixed Observatory and finding circles:

W. E. Sperra 3-inch refractor.	J. A. Parkhurst. 6.2-inch reflector.	F. F. Arnold. 5-inch refractor.	W. Dearden. 9.5-inch reflector.
103 T Andromedæ	103	103	
320 U Cephei			
	678 U Persei		
	906 R Trianguli	906	
	814 S Persei		
	980 V Persei		
1574 W Tauri	1574	1574	1574
1623 T Camelopardalis	1623		1623
1805 V Orionis	1805		
1981 S Camelopardalis	1981	1981	1981
2100 U Orionis	2100		
	2258 V Aurigæ		2258
2815 U Geminorum	2815	2815	2815
3186 T Cancri			3890
3493 R Leonis			4300
3825 R Ursæ Majoris	3825	3825	4315
4511 T Ursæ Majoris			4492
4521 R Virginis			
4557 S Ursæ Majoris			4557
4805 W Virginis			
4826 R Hydræ			
4847 S Hydræ			5070
5157 S Boötis	5157		
	5190 R Camelopardalis		5190
5194 V Boötis	5194		
5237 R Boötis			
	5338 U Boötis		5338
5675 V Coronæ	5675		
	5887 V Ophiuchi		
		5955 R Draconis	
6207 Z Ophiuchi	6207		
7085 R T Cygni	7085	7085	
	7118 X Aquilæ		
	7220 S Cygni	7220	7220
7437 X Cygni			
	7458 V Delphini		
	8324 V Cassiopeæ		8324



103 T ANDROMEDÆ.

This star is B. D. + 26°.43. Its position for 1900 is
R. A. $0^h\ 17^m\ 10^s$. Decl. + 26° 26′.4.

An account of its discovery and discordant observations was given in POPULAR ASTRONOMY, Vol. I, p. 462. It has recently passed a maximum. My observations, fourteen in number, beginning 1894, Nov. 15, and ending 1895, Jan. 7, locate the maximum at 1894, Dec. 3, $7^m.6$. Mr. Sperra sends me six observations from Dec. 4 to 31, beginning too late (according to my observations) to determine the time of maximum. The light curve drawn from my observations, is quite flat near the maximum, making the exact date of that phase uncertain by two or three days.

Mr. Arnold has 11 observations from Nov. 17 to Jan. 7, giving a maximum 1894, Dec. 4, $7^m.4$. In the figure for T Andromedæ, Mr. Arnold's observations are connected by short dotted lines, mine by full lines, and the light curve is drawn to satisfy, as well possible, both sets of observations. The date of maximum thus found, 1894, Dec. 4, agrees exactly with Mr. Yendell's results published in No. 335 of the *Astronomical Journal*, where a period of 265.35 days is deduced.

320 U CEPHEI.

Mr. Sperra has observed two more minima of this interesting "Algol type" variable. 1894, Dec. 4, he made seventeen observa-

tions, beginning at $13^h\ 37^m$ Gr. Mean Time, and ending at $20^h\ 52^m$. The resulting minimum is

1894, Dec. 4, $17^h\ 42^m$ Gr. M. T.

Also on Dec. 19 he made seventeen observations from $13^h\ 20^m$ to $19^h\ 39^m$ deducing a minimum:

1894, Dec. 19, $16^h\ 48^m$ Gr. M. T.

814 S Persei.

The chart for this variable is given in Vol. I, p. 216. It is one of the longest period stars known, it being given by Hagen as 852 days; by Safarik as 814 to 952 days. I have watched it since 1892, Nov. 18, and have forty-three observations between that date and 1894, Nov. 27, yielding a minimum 11^m, 1893, April 25 and a maximum $8^m.6$, 1894, May 1.

2815 U Geminorum.

Mr. Sperra was fortunate enough to secure two observations near the past maximum. His record is:

		Gr. M. T.	
1894	Dec. 4,	17^h	U not seen, "g" ($12^m.3$) easily seen.
	6,	22	U $9^m.6$
	8,	21	U $10^m.0$

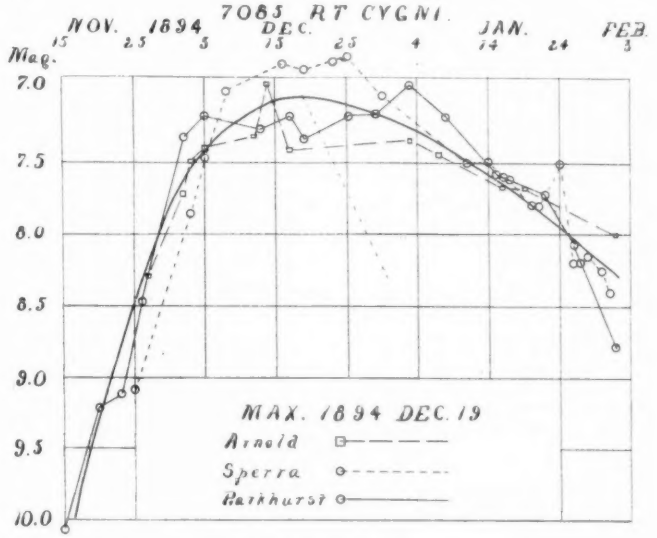
Mr. Arnold made one observation:

Dec. 8, 16^h U $10^m.5$

These three observations would not definitely determine whether the maximum occurred before or after the observation of the 6th. A reference to Vol. I, p. 400 will show that the maximum may occur 2 or 8 days before the variable falls to 10^m. I think that the evidence favors 1894, Dec. 6.0, Gr. M. T. as the probable date of maximum. The following are all the maxima which I can find published:

Calendar Date.	Julian Date.	Interval.
1891 Jan. 8.5	2411741	
		99 *d*
Nov. 1	2038	
		86
1892 Jan. 26	2124	
		66
Apr. 1	2190	
		86
Dec. 14.5	2447	
		134 or 67
1893 Apr. 27	2581	
		75
Dec. 8.0	2806	
		100
1894 Mar. 18	2906	
		88
Dec. 6	3169	

As the interval varies from 66 to 100 days the next maximum may be expected at any time from Feb. 10 to Mar. 16. The star will then be favorably situated for evening observation, and the place should be examined every clear evening in February and March.



7085 R T Cygni.

The observations of Arnold, Sperra, and Parkhurst, 49 in number, are plotted together, the curve giving Dec. 19 as the date of maximum. The observations treated separately yield the following results:

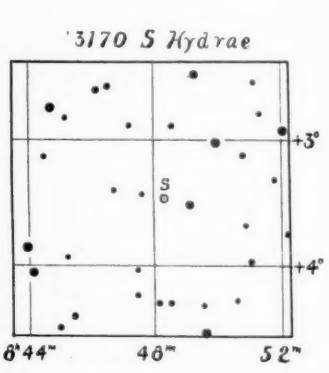
Arnold from	12 obs.	Dec. 20
Sperra from	20 obs.	Dec. 17
Parkhurst from	17 obs.	Dec. 21

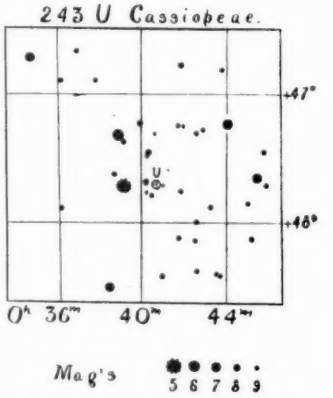
The above date from the mean curve, Dec. 19, is 9 days later than Chandler's prediction. The date of the previous maximum, taking the mean of four observers, was 1894 June 14, which is 11 days later than Chandler's prediction, and 11 days earlier than Hartwig's. Only four years have elapsed since this star was found to vary, so its period has not been determined with accuracy.

8324 V Cassiopeæ.

This variable which is charted in Vol. II, p. 218, passed a minimum 1894, Nov. 24, $12^{m}.3$. I observed a minimum 1894, Mar.

21. The interval between these is 248 days. This star was not seen by the Durchmusterung observers 1857, Aug. 26, it was observed 9^m.5, 1857, Aug. 30, and Sept. 16. It was then evidently on the ascending branch of its light curve, and as it reaches 9^m.5 about 60 days after minimum, that phase occurred about 1857, July 10. The interval between this date and 1894, Mar. 21 is 13404 days, or 54 periods of 248.2 days each.





Charts are given for two more variables. A maximum of 243 is due in April, so that observations should begin at once. Feb. 1 it was about 10^m.5. The 5^m star omicron Cassiopeæ, 2 minutes preceding will aid in finding the variable. 3170 is now about at its maximum, but no observations of minima are on record. The star may be too near the Sun at its minimum in the summer of 1895, but in 1896 it will be in good position.

FROM CHANDLER'S SECOND CATALOGUE.

Star.	Position 1900. R. A. h m s	Decl. ° ′	Redness.	Magnitude Max.	Min.	Period
243 U Cassiopeæ	0 40 46	+ 47 42.6	6	8.0—8.8	<15	276.0
3170 S Hydræ	8 48 21	+ 3 26.7	2.1	7.5—8.7	<12.2	257.0

MARENGO, Ill., 1895 Feb. 8.

To find the orbit of α Centauri divide the semi-axis of its apparent orbit by its parallax, and the quotient will equal its semi-axis in miles divided by Earth's distance from the Sun, as follows:

$$\frac{17''.5}{.75''} = \frac{\text{Semi-axis of orbit in miles}}{93{,}000{,}000}$$

BARNARD'S PERIODIC COMET 1884 II.

H. C. WILSON.

Two periodic comets should return to perihelion this summer: Brorsen's, which has been lost since 1879, and Barnard's comet 1884 II. The latter was in an unfavorable position for observation in 1890 and escaped detection. This year it will be somewhat more favorably situated and we hope that some of our readers may be able to find it. In a recent number of the *Astronomische Nachrichten* Dr. Berberich has given three search ephemerides for this comet, extending from April 24 to July 5. We have charted these ephemerides on the plate which forms the frontispiece to this number of POPULAR ASTRONOMY, so as to show graphically to our readers the apparent course of the comet through the constellations. The ephemerides will be given in the next number.

According to Dr. Berberich's computations the comet will pass the perihelion point of its orbit June 3, but this time is uncertain by about 8 days. It may be 8 days early or 8 days late. This renders it uncertain just what course the comet will take across the sky. The middle line of the three on the chart, will represent the path of the comet, should it pass perihelion on the calculated date. The finer lines on either side will represent the path, the upper one if the comet is 8 days early, the lower one if it is 8 days late. It may be anywhere between the two. The comet signs on the lines show the places of the comet at midnight of every fourth day. The dotted lines connect the same dates on the different paths and show over what region the observer should search on any date.

In 1884 the comet was rather faint and diffuse. Barnard described it as "large for a telescopic comet; gradually a little brighter in the middle" * * * * * * * "spreads out into hazy indeterminate outlines." This year the calculated brightness is only from one-seventh to one-fifth of that which it had when discovered in 1884, but is from two to three times as great as when it was last seen in that year. The searcher will, therefore, not expect to find a very bright object, but on the other hand it will take extremely careful searching, a keen eye, a good telescope and just the right eyepiece. It may not be necessary to have a large telescope, since Mr. Barnard in 1884 was able to see the comet with a five-inch telescope, after it had become invisible to him in a six-inch telescope at the same place.

The comet must be looked for in the morning an hour or more before sunrise. During April and May it will be almost too far south for observers in our latitude, but those in the southern hemisphere will have a favorable opportunity. In June and July the conditions will be much better for us and the comet will be at its greatest brightness for this apparition.

A few suggestions as to the method of search may be useful. We suppose the observer to have a four or five inch telescope with several eyepieces of different powers. For searching it will probably be best to use the lowest power, which gives a field of a degree or more. Set up the telescope so that the polar axis points approximately towards the north pole. Direct the telescope towards the region of the sky indicated for the date on the chart and, beginning at one end of the dotted line, sweep slowly toward the other noting every change in the luminosity or blackness of the background of the sky; move the telescope north or or south one-half the diameter of the field of view and sweep backward; move the telescope again an equal amount in the same direction and sweep forward. Repeat these operations until the whole region for 1° or 2° on either side of the proper dotted line has been carefully swept over. It may be well to repeat the sweeps using an eyepiece of higher power.

In case a nebulous looking object is found, do not at once expect it to be the comet, for there are many faint nebulæ all over the sky. Note carefully the position of some stars near the object, so that you can recognize them again, and make a sketch of them. On the next morning look at the same region and see whether the suspected object has moved or not. If it has, hunt it up, determine its right ascension and declination, as closely as you can from the chart, and telegraph the same to Harvard College Observatory. Do not be disappointed if some one is ahead of you. There is a great deal of satisfaction in having made an independent discovery, even though it be some hours or days later than that of another person.

PLANET NOTES FOR APRIL.

H. C. WILSON.

Mercury will be morning planet during April, but will not be in good position for observation because of his proximity to the Sun. Toward the end of the month he will be on the farther side of his orbit nearly in line with the Sun.

We hope that during the first half of February many of our readers have

been able to identify the planet. There were several nights at Northfield when between 6:00 and 7:00 P. M., Mercury was quite conspicuous, although far outshown by his brilliant neighbor, Venus. The two planets made a splendid pair and it was interesting to watch their changing positions from night to night, as the little "messenger" approached the "fair goddess," passed by her, turned, passed again and returned toward the Sun.

Venus during April will increase slowly in brightness, the light numbers for the first and last of the month being 62 and 73. Her phase will be gibbous, 0.833 of the disc being illuminated at the middle of the month. The Moon will pass Venus on the afternoon of April 27. Venus will pass Neptune, the former 3° to the north of the latter at 5 P. M., April 29.

Mars and *Jupiter* will be in conjunction in the western corner of Gemini on the evening of April 25. Mars will then be about a degree and a half north of Jupiter. Both planets are moving eastward but Mars much more rapidly than Jupiter so that they will not be long together. The Moon will pass by the two on the morning of April 29.

Saturn will be at opposition on the morning of April 24, and so will be visible during the greater part of the night. We give this month among the tables a diagram showing the orbits of seven of the satellites of Saturn. The outer one, Iapetus, has so large an orbit that it is not convenient to represent it on the diagram with the others. Those who saw the diagram of the satellite orbits for last year will notice that this is considerably wider, relative to the length. This is because Saturn has moved around farther in his orbit, while the plane of his rings and satellite orbits maintains the same direction in space, so that we look upon them more nearly broadside. To determine the position of a satellite at any time, look in the tables for the last preceding time of eastern elongation of that satellite; subtract this time from the given time; reduce the interval to days and fractions of a day. If the interval be only a fraction of a day its position will be between the points marked 0 and 1*d* on the diagram, if one day and fraction it will be between the points marked 1*d* and 2*d*, etc. The inner satellite, Mimas, can be seen only when near the east or west end of its orbits, and the others, Enceladus, Tethys and Dione can be seen best when past the ends of the rings.

Uranus is nearing opposition and can be observed during the latter half of the night. We give in the tables the times of north and south elongations of the satellites, with a diagram showing the relative positions of their orbits. These satellites are difficult objects but perhaps some of our readers will be able to see and identify the two outer ones. Do not attempt it with anything less than a 10-inch telescope. Uranus is in Libra near the star ν.

Neptune is past good position for observation.

Remember the total eclipse of the Moon March 10. The data were given in our last number. It begins at 7:54 and ends at 11:25 P. M., Central Standard Time.

Planet Tables for April.

[The times given are local time for Northfield. To obtain Standard Times for places in approximately the same latitude, add the difference between Standard and Local Time if west of the Standard Meridian or subtract if east].

MERCURY.

Date.	R. A.	Decl.	Rises.	Transits.	Sets.
	h m	° ′	h m	h m	h m
Apr. 5.....	23 30.5	− 5 50	4 57 A. M.	10 36.8 A. M.	4 17 P. M.
15.....	0 28.0	+ 0 25	4 51 "	10 55.7 "	5 00 "
25.....	1 34.6	+ 8 14	4 48 "	11 24.0 "	6 00 "

VENUS.

Apr.	5.....	2	51.5	+16	53	6	43	A. M.	1	56.5	P. M.	9	09	P. M.
	15.....	3	40.2	+20	31	6	36	"	2	5.8	"	9	36	"
	25.....	4	30.7	+23	15	6	33	"	2	16.6	"	10	01	"

MARS.

Apr.	5.....	5	16.8	+24	37	8	30	A. M.	4	21.5	P. M.	12	12	A. M.
	15.....	5	49.9	+24	55	8	16	"	4	8.2	"	12	01	"
	25.....	6	09.3	+24	56	8	03	"	3	55.2	"	11	48	P. M.

JUPITER.

Apr.	5.....	5	57.0	+23	28	9	16	A. M.	5	1.2	P. M.	12	46	A. M
	15.....	6	03.1	+23	29	8	43	"	4	28.0	"	12	13	"
	25.....	6	10.0	+23	29	8	10	"	3	55.5	"	11	40	P. M.

SATURN.

Apr.	5.....	14	15.8	−10	45	7	58	P. M.	1	18.0	A. M.	6	38	A. M.
	15.....	14	13.0	−10	30	7	15	"	12	36.0	"	5	51	"
	25.....	14	10.1	−10	14	6	32	"	11	53.8	P. M.	5	16	"

URANUS.

Apr.	5.....	15	8.3	−17	12	9	17	P. M.	2	09.7	A. M.	7	03	A. M.
	15.....	15	6.6	−17	6	8	26	"	1	19.2	"	6	13	"
	25.....	15	4.3	−17	2	7	50	"	12	44.2	"	5	38	"

NEPTUNE.

Apr.	5.....	4	49.2	+21	0	8	21	A. M.	3	53.4	P. M.	11	25	P. M.
	15.....	4	50.2	+21	2	7	43	"	3	15.3	"	10	47	"
	25.....	4	51.4	+21	5	7	05	"	2	36.9	"	10	09	"

THE SUN.

Apr.	5.....	0	57.8	+	6	11	5	34	A. M.	12	2.7	P. M.	6	32	P. M.
	15.....	1	34.5	+	9	51	5	16	"	12	0.0	M.	6	44	"
	25.....	2	11.8	+13	16		5	00	"	11	57.9	A. M.	6	56	"

Occultations Visible at Washington.

Date 1895	Star's Name.	Magnitude.	IMMERSION. Washington M. T.	IMMERSION. Angle from N p't.	EMERSION. Washington M. T.	EMERSION. Angle from N p't.	Duration.
			h m	°	h m	°	h m
Apr. 2	47 Geminorum	6.0	7 02	161	7 48	23	0 46
11	C Scorpii	5.3	18 20	50	19 05	327	0 45
29	W. vi 1656	8.2	10 18	88	11 07	305	0 49

Phases and Aspects of the Moon.

		Central Time. d	h	m	
First Quarter	Apr.	2	3	28	P. M.
Perigee		6	10	30	"
Full Moon		9	7	43	A. M.
Last Quarter		16	5	22	P. M.
Apogee		18	6	40	"
New Moon		24	7	11	"

Jupiter's Satellites for April.

Phases of the Eclipses of the Satellites for an Inverting Telescope.

I. r

III. d r

II. r

IV. d r

Configurations at 8h 0m for an Inverting Telescope.

Day.	West.	East.
1	·3 2· ·1	○ 4·
2	4· ·2 ·3	○ 1·
3	4· ·1	○ ·3 ·2
4	4·	○ 1.2· ·3
5	4· 2·	○ 3· ·1●
6	○3· ·4 1·	○ ·2●
7	·4 3·	○ ·1 2·
8	·4·3 1.2·	○
9	·3 ·2 ·4	○ 1
10	·1	○ ·4 ·3 ·2
11		○ 1.2· ·4 ·3
12	2·●	○ 3· ·4 ·1●
13	1·	○ 3· ·4 ·2●
14	3·	○ ·1 2· 4·
15	3· 1· 2·	○ 4·
16	·3 ·2	○ ·1 4·
17	·1	○ ·2 4· ·3●
18		○4· 1·2· ·3
19	2.4· ·1	○ 3·
20	○1· 4· 2·	○ 3·
21	·4 3·	○ ·1 2·
22	·4 3· 1· 2·	○
23	·4 ·3 ·2	○ ·1
24	·4 ·1	○ ·2 ·3●
25	·4	○ 1·2· 3·
26	2· ·4 ·1	○ 3·
27	·2	○1· 3· ·4●
28	3·	○ ·2 ·4 ·1●
29	○2· 3· 1·	○ ·4
30	·3 ·2	○ ·1 ·4

Phenomena of Jupiter's Satellites.

Central Time.

Apr.	1	11	27	A. M.	I	Sh. Eg.	Apr.	10	1	55	P. M.	IV	Oc. Dis.
		11	29	"	II	Sh. In.			3	06	"	III	Ec. Dis.
		11	38	"	II	Tr. Eg.			3	46	"	IV	Oc. Re.
		2	11	P. M.	II	Sh. Eg.			6	05	"	III	*Ec. Re.
	2	5	9	A. M.	IV	Tr. In.		11	1	27	A. M.	IV	Ec. Dis.
		5	10	"	I	Oc. Dis.			1	38	"	I	Oc. Dis.
		6	19	"	IV	Tr. Eg.			3	51	"	IV	Ec. Re.
		8	42	"	I	Ec. Re.			5	06	"	I	Ec. Re.
		4	27	P. M.	IV	Sh. In.			10	49	P. M.	I	Tr. In.
		6	51	"	IV	*Sh. Eg.		12	12	02	A. M.	I	Sh. In.
	3	2	23	A. M.	I	Tr. In.			1	02	"	II	Tr. In.
		3	26	"	II	Oc. Dis.			1	07	"	I	Tr. Eg.
		3	38	"	I	Sh. In.			2	20	"	I	Sh. Eg.
		4	40	"	I	Tr. Eg.			3	26	"	II	Sh. In.
		5	56	"	I	Sh. Eg.			3	43	"	II	Tr. Eg.
		5	57	"	III	Oc. Dis.			6	09	"	II	Sh. Eg.
		8	35	"	II	Ec. Re.			8	07	P. M.	I	*Oc. Dis.
		8	56	"	III	Oc. Re.			11	35	"	I	Ec. Re.
		11	07	"	III	Ec. Dis.		13	5	19	"	I	Tr. In.
		2	4	P. M.	III	Ec. Re.			6	31	"	I	*Sh. In.
		11	39	"	I	Oc. Dis.			7	27	"	II	*Oc. Dis.
	4	3	11	A. M.	I	Ec. Re.			7	36	"	I	*Tr. Eg.
		8	52	P. M.	I	*Tr. In.			8	49	"	I	*Sh. Eg.
		10	07	"	I	*Sh. In.		14	12	19	A. M.	III	Tr. In.
		10	20	"	II	*Tr. In.			12	28	"	II	Ec. Re.
		11	9	"	I	Tr. Eg.			3	19	"	III	Tr. Eg.
	5	12	25	A. M.	I	Sh. Eg.			5	8	"	III	Sh. In.
		12	48	"	II	Sh. In.			8	16	"	III	Sh. Eg.
		12	59	"	II	Tr. Eg.			2	37	P. M.	I	Oc. Dis.
		3	31	"	II	Sh. Eg.			6	04	"	I	*Ec. Re.
		6	9	P. M.	I	*Oc. Dis.		15	11	48	A. M.	I	Tr. In.
		9	40	"	I	*Ec. Re.			12	59	P. M.	I	Sh. In.
	6	3	21	"	I	Tr. In.			2	06	"	I	Tr. Eg.
		4	36	"	I	Sh. In.			2	24	"	II	Tr. In.
		4	46	"	II	Oc. Dis.			3	18	"	I	Sh. Eg.
		5	38	"	I	Tr. Eg.			4	44	"	II	Sh. In.
		6	54	"	I	*Sh. Eg.			5	05	"	II	Tr. Eg.
		8	07	"	III	*Tr. In.			7	28	"	II	*Sh. Eg.
		9	53	"	II	*Ec. Re.		16	9	07	A. M.	I	Oc. Dis.
		11	06	"	III	Tr. Eg.			12	33	P. M.	I	Ec. Re.
	7	1	07	A. M.	III	Sh. In.		7	6	18	A. M.	I	Tr. In.
		4	15	"	III	Sh. Eg.			7	28	"	I	Sh. In.
		12	38	P. M.	I	Oc. Dis.			8	35	"	I	Tr. Eg.
		4	8	"	I	Ec. Re.			8	47	"	II	Oc. Dis.
	8	9	50	A. M.	I	Tr. In.			9	46	"	I	Sh. Eg.
		11	05	"	I	Sh. In.			1	46	P. M.	II	Ec. Re.
		11	41	"	II	Tr. In.			2	20	"	III	Oc. Dis.
		12	07	P. M.	I	Tr. Eg.			5	21	"	III	Oc. Re.
		1	22	"	I	Sh. Eg.			7	6	"	III	*Ec. Dis.
		2	07	"	II	Sh. In.			10	6	"	III	*Ec. Re.
		2	21	"	II	Tr. Eg.		18	3	36	A. M.	I	Oc. Dis.
		4	50	"	II	Sh. Eg.			7	01	"	I	Ec. Re.
	9	7	8	A. M.	I	Oc. Dis.			11	36	P. M.	IV	Tr. In.
		10	37	"	I	Ec. Re.		19	12	48	A. M.	I	Tr. In.
	10	4	20	"	I	Tr. In.			1	39	"	IV	Tr. Eg.
		5	33	"	I	Sh. In.			1	59	"	I	Sh. In.
		6	06	"	II	Oc. Dis.			3	5	"	I	Tr. Eg.
		6	37	"	I	Tr. Eg.			3	47	"	II	Tr. In.
		7	51	"	I	Sh. Eg.			4	15	"	I	Sh. Eg.
		10	07	"	III	Oc. Dis.			6	03	"	II	Sh. In.
		11	11	"	II	Ec. Re.			6	27	"	II	Tr. Eg.
		1	07	P. M.	III	Oc. Re.			8	47	"	II	Sh. Eg.

Apr.	19	10 26 A. M.	IV	Sh. In.	
		1 05 P. M.	IV	Sh. Eg.	
		10 6 "	I	Oc. Dis.	
	20	1 31 A. M.	I	Ec. Re.	
		7 17 P. M.	I	*Tr. In.	
		8 26 "	I	*Sh. In.	
		9 35 "	I	*Tr. Eg.	
		10 8 "	II	*Oc. Dis.	
		10 44 "	I	Sh. Eg.	
	21	3 04 A. M.	II	Ec. Re.	
		4 33 "	III	Tr. In.	
		7 34 "	III	Tr. Eg.	
		9 07 "	III	Sh. In.	
		12 17 P. M.	III	Sh. Eg.	
		4 36 "	I	Oc. Dis.	
		7 59 "	I	*Ec. Re.	
	22	1 47 "	I	Tr. In.	
		2 54 "	I	Sh. In.	
		4 04 "	I	Tr. Eg.	
		5 9 "	II	Tr. In.	
		5 12 "	I	Sh. Eg.	
		7 22 "	II	*Sh. In.	
		7 50 "	II	*Tr. Eg.	
		10 06 "	II	Sh. Eg.	
	23	11 06 A. M.	I	Oc. Dis.	
		2 28 P. M.	I	Ec. Re.	
	24	8 17 A. M.	I	Tr. In.	
		9 23 "	I	Sh. In.	
		10 34 "	I	Tr. Eg.	
		11 30 "	II	Oc. Dis.	
		11 41 "	I	Sh. Eg.	
		4 22 P. M.	II	Ec. Re.	
		6 36 "	III	*Oc. Dis.	
		9 38 "	III	*Oc. Re.	
		11 07 "	III	Ec. Dis.	
	25	2 7 A. M.	III	Ec. Re.	
		5 36 "	I	Oc. Dis.	
		8 57 "	I	Ec. Re.	
	26	2 47 A. M.	I	Tr. In.	
		3 52 "	I	Sh. In.	
		5 04 "	I	Tr. Eg.	
Apr.	26	6 10 "	I	Sh. Eg.	
		6 32 "	II	Tr. In.	
		8 41 "	II	Sh. In.	
		9 13 "	II	Tr. Eg.	
		11 25 "	II	Sh. Eg.	
		12 06 P. M.	I	Oc. Dis.	
	27	3 26 A. M.	I	Ec. Re.	
		9 15 "	IV	Oc. Dis.	
		11 28 "	IV	Oc. Re.	
		7 29 P. M.	IV	*Ec. Dis.	
		9 17 "	I	*Tr. In.	
		10 07 "	IV	Ec. Re.	
		10 21 "	I	Sh. In.	
		11 34 "	I	Tr. Eg.	
	28	12 38 A. M.	I	Sh. Eg.	
		12 52 "	II	Oc. Dis.	
		5 40 "	II	Ec. Re.	
		8 49 "	III	Tr. In.	
		11 52 "	III	Tr Eg.	
		1 07 P. M.	III	Sh. In.	
		4 17 "	III	Sh. Eg.	
		6 36 "	I	*Oc. Dis.	
		9 55 "	I	Ec. Re.	
	29	3 46 "	I	Tr. In.	
		4 50 "	I	Sh. In.	
		6 03 "	I	Tr. Eg.	
		7 07 "	I	*Sh. Eg.	
		7 55 "	II	*Tr In.	
		9 59 "	II	Sh. In.	
		10 36 "	II	Tr. Eg.	
	30	12 44 A. M.	II	Sh. Eg.	
		1 06 P. M.	I	Oc. Dis.	
		4 24 "	I	Ec. Re.	
May	1	10 16 A. M.	I	Tr. In.	

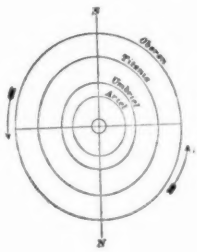
NOTE.—In., denotes ingress; Eg., egress; Dis., disappearance; Re., reappearance; Ec., eclipse. Oc., denotes occultation; Tr., transit of the satellite; Sh. transit of the shadow; * Visible at Washington.

Satellites of Uranus.

[N = north elongation; S = south elongation]

ARIEL. PERIOD $2^d\ 12^h.489$.

Apr.	1	3.7 A. M.	N	Apr.	22	1.8 P. M.	S
	2	9.9 "	S		23	8.0 "	N
	3	4.2 P. M.	N		25	2.3 A. M.	S
	4	10.4 "	S		26	8.6 "	N
	6	4.6 A. M.	N		27	2.8 P. M.	S
	7	10.8 "	S		28	9.1 "	N
	8	5.1 P. M.	N		30	3.3 A. M.	S
	9	11.3 "	S				
	11	5.6 A. M.	N				
	12	11.8 "	S				
	13	6 1 P. M.	N				
	15	12.4 A. M.	S				
	16	6.6 "	N				
	17	12.9 P. M.	S				
	18	7.1 "	N				
	20	1.3 A. M.	S				
	21	7.6 A. M.	N				



Apparent Orbits of the Satellites of Uranus in 1895.

UMBRIEL. PERIOD $4^d\ 3^h.460$.

Apr.	2	10.3 A. M. S	Apr.	12	7.0 P. M. N	Apr.	23	3.7 A. M. S
	4	12.1 P. M. N		14	8.7 " S		25	5.4 " N
	6	1.8 " S		16	10.4 " N		27	7.1 " S
	8	3.5 " N		19	12.2 A. M. S		29	8.9 " N
	10	5.2 " S		21	1.9 " N			

TITANIA. PERIOD $8^d\ 16^h.942$.

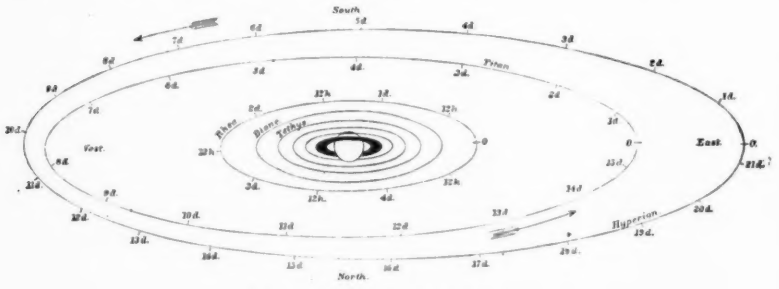
Apr.	2	10.4 P. M. N	Apr.	15	11.9 P. M. S	Apr.	24	4.9 P. M. S
	7	6.9 A. M. S		20	8.4 A. M. N		29	1.4 A. M. N
	11	3.4 P. M. N						

OBERON. PERIOD $13^d\ 11^h.119$.

Apr.	2	3.4 A. M. N	Apr.	15	2.7 P. M. N	Apr.	29	1.9 A. M. N
	8	9.0 P. M. S		22	8.3 A. M. S			

Saturn's Satellites.

[E = east elongation; I = inferior conjunction (south of planet); W = west elongation; S = superior conjunction (north of planet). In the diagram the points of the orbits marked O are those of eastern elongation, as seen in an inverting telescope. The Central Standard times when the satellites will be at these points are given in the tables that follow. The points on the orbits marked $1d$, $2d$, etc., indicate the places of the satellites at the intervals 1 day, 2 days, etc., after the time given for eastern elongation.]



I MIMAS. PERIOD $0^d\ 22^h.6$.

		h			h			h
Apr.	1	11.7 P. M. E	Apr.	11	9.1 P. M. W	Apr.	20	8.0 P. M. E
	2	10.3 " E		12	7.7 " W		24	3.1 A. M. W
	3	8.9 " E		16	2.9 A. M. E		25	1.7 " W
	8	2.7 A. M. W		17	1.5 " E		26	12 3 " W
	9	1.3 " W		18	12.1 " E		26	11.0 P. M. W
	9	11.9 P. M. W		18	10.7 P. M. E		27	9.6 " W
	10	10 5 " W		19	9.3 " E		28	8.2 " W

II ENCELADUS. PERIOD $1^d\ 8^h.9$.

Apr.	2	1.0 A. M. E	Apr.	12	11.9 P. M. E	Apr.	23	10.9 P. M. E
	3	9.8 " E		14	8.8 A. M. E		25	7.8 A. M. E
	4	6.7 P. M. E		15	5.7 P. M. E		26	4.7 P. M. E
	6	3.6 A. M. E		17	2.5 A. M. E		28	1.6 A. M. E
	7	12.4 P. M. E		18	11 4 A. M. E		29	10.4 " E
	8	9.3 " E		19	8.3 P. M. E		30	7.3 P. M. E
	10	6.2 A. M. E		21	5.2 A. M. E			
	11	3.1 P. M. E		22	2.0 P. M. E			

III Tethys. Period 1*d* 21^h.3.

Apr.	1	2.6 A. M. E	Apr.	12	10.3 A. M. E	Apr.	23	6.1 P. M. E
	2	11.9 P. M. E		14	7.6 " E		25	3.3 " E
	4	9.2 " E		16	4.9 " E		27	12.6 " E
	6	6.5 " E		18	2.2 " E		29	9.9 " E
	8	3.7 " E		19	11.5 P. M. E			
	10	1.0 " E		21	8.8 " E			

IV Dione. Period 2*d* 17^h.7.

Apr.	1	10.5 P. M. E	Apr.	12	9.1 P. M. E	Apr.	23	7.7 P. M. E
	4	4.1 " E		15	2.7 " E		26	1.3 " E
	7	9.8 A. M. E		18	8.4 A. M. E		29	7.0 A. M. E
	10	3.5 " E		21	2.0 " E			

V Rhea. Period 4*d* 12^h.4.

Apr.	4	2.4 A. M. E	Apr.	17	3.4 P. M. E			
	8	2.8 P. M. E		22	3.7 A. M. E			
	13	3.1 A. M. E		26	4.1 P. M. E			

VI Titan. Period 15*d* 3^h.3.

Apr.	3	11.9 A. M. I	Apr.	15	12.1 P. M. E	Apr.	23	1.1 P. M. W
	7	3.9 P. M. W		19	9.3 A. M. I		27	2.2 " S
	11	4.8 " S						

VII Hyperion. Period 21*d* 7^h.8

Apr.	5	2.1 A. M. I	Apr.	14	9.4 A. M. S	Apr.	26	6.8 A. M. I
	9	9.4 P. M. W		20	3.6 " E			

VIII Japetus. Period 79*d* 22^h.0.

Mar.	13	11.1 P. M. I	Apr.	3	5.3 A. M. W	Apr.	23	8.9 A. M. S

PRACTICAL SUGGESTIONS.

If you do not know, ask, for probably some one can answer. Questions and answers should be brief generally.

89. Two observers state in *Monthly Notices* that recently in a moment of supreme definition a Martian canal was resolved in to separate points or something like that in effect. Has the observation been made elsewhere? If so, what explanation can be given? A. B.

Answer. We are not aware that other such observations have been made. The attention of astronomers is called to this matter.

90. What is the sky? T. C. R.

Recently we received a full and well written letter from a person who evidently knows how to think and how to express his thoughts in writing. Having given his attention somewhat to the above query, he believed he had reached some conclusions which were based on sound reasoning. The first was that the sky is beyond the stars. The facts which appear to prove this are three, viz:—

1. The sky has color. 2. The blue of the sky becomes intensified to the eye when observed from the tops of mountains, or in elevated regions where there is scarcity of vapor and rarity of atmosphere. 3. The blue of the sky does not intercept or impair the light of the stars.

The conclusions that the sky is beyond the stars reached by our correspondent must mean that the source of the blue of the sky is beyond the stars. The fact that the blue of the sky is intensified, for instance, when observed from the tops of mountains rather supports the idea that the blue color is an atmospheric phenomenon, rather than one produced in the far-off star spaces. Again we can not certainly affirm that light does not lose something, or is not some way changed in passing through the vast depths of ethereal space. We wish we had definite knowledge concerning the possible varying conditions of light as it sweeps through space with the awful velocity of 186,000 miles per second. Ether is probably the vehicle of its flight. Tyndall's papers "On a New Series of Chemical Reactions produced by Light," and "On the Blue Color of the Sky, etc," are good reading for those interested in this and similar themes. Ganot's Physics gives a good summary of Tyndall's researches on the same subject.

91. What is the construction and use of the objective prism? W. J. G.

Answer: The objective prism, so-called, gets its name from its position with reference to the object-glass of the telescope. It is usually placed in a box and attached to the telescope outside of the objective so as to intercept the rays of light from and celestial object under examination. By this means a larger image of the spectrum may be obtained than is possible if the prism is used in connection with the eye-piece of the instrument. For great dispersive effect a train of prisms may be used in the same way if desired. By referring to Young's General Astronomy, page 490, an illustration and a description of this apparatus may be found. Such a prism could be used with a 3-inch telescope.

92. (1.) Would it be possible to photograph the three cometary spectra bands (in usual conditions) of a comet of the 7th or 8th magnitude by an exposure of about ten seconds by using the camera with such a focus, as would be necessary to make the exposure in such a time? If not, what time would be necessary? Please be sure and give the *least possible* time only.

(2.) Do the cometary band (inusual conditions) always appear on the same place on the spectrum scale?

Answer: (1.) The exposure required for photographing the spectrum of a faint comet is a matter of hours rather than of seconds. An under-exposed image might be obtained in one hour.

(2.) The great majority of comets have a banded spectrum, the sharp edges of the brightest bands being at 5635, 5165 and 4737 on the wave-length scale. Many other lines have been photographed in the violet, notably by Campbell. Considerable deviations from the usual type have been recorded, but they are possibly explained by the difficulty of the observations. A few comets have continuous spectra. J. E. K.

GENERAL NOTES.

The publisher of this journal very much desires ten copies each of the January and December numbers of *Astronomy and Astro-Physics* for 1894. Forty cents each will be paid for these numbers if returned soon in good condition.

Attention is called to the fact that this office can still supply complete sets of the *Sidereal Messenger* consisting of ten volumes, and also, the three large vol-

umes of *Astronomy and Astro-Physics* for the years 1892, 1893 and 1894. The thirteen volumes represent astronomy from 1882 to 1894 inclusive. See advertisement for more specific statement.

In matter this number is especially strong, although needing less illustration than usual. A number of excellent articles calling for full and expensive engraving are already in hand for April. Some of these articles would have appeared in this issue but for failure of cuts in the hands of the engraver. The next number will be a superior one in both particulars.

The Study of Astronomy.—Doctor See continues in this number his discussion of the study of Physical Astronomy in the United States, and points out the peculiar difficulties which will be recognized by all who have given serious consideration to the future of American Astronomy. His lucid statement of the real interests of science and of the educational value of an exact science like Physical Astronomy ought to be of service to the schools and colleges of this country. We believe it will prove both timely and valuable to those students and amatuers who are to become the astronomers of the future, and will be an inspiration to the friends of solid astronomical work.

Professor George E. Hale Awarded the Janssen Prize.—We notice with pleasure, that professor George E. Hale of the University of Chicago has been awarded the Janssen prize which is one of the high honors within the gift of the French Academy of Sciences. On the 9th of January last, he received a letter from Professor Janssen himself, who is the director of the national Astrophysical Observatory and who established the prize, saying that he had been directed by the commission making the award, to forward him the medal.

The Janssen prize of the academy was established by Professor Janssen in 1887, and the medals have been awarded each year since then to the scientist which a commission appointed for the purpose considers has made the greatest advance in astrophysics. Prof. Hale is the third American to receive the honor, medals having been awarded to Professor Young of Princeton University and Professor Langley, secretary of the Smithsonian Institution. Their work, like that of Professor Hale, was upon the sun. The commission appointed to award the medal for 1894 was composed of President Loewy of the French academy, Professor Janssen, Professor Tisserand, director of the Paris Observatory, Professor Wolf and Professor Faye, prominent astronomers of France.

The award is a deserved one, and is another victory for American astronomy. Hearty congratulations are hereby given to our former associate in editorial work.

Negatives for Lantern Slides.—In our observatories where practical work is being done in photography there is more or less call for positives in the form of lantern slides by lecturers on astronomy and teachers in high schools, academies, colleges and universities. This is very natural, as there is no better way of impressing on the minds of students or public assemblies the important facts of recent astronomical research than by the use of good lantern slides. This means of illustration, however, should be good—as nearly perfect as possible—or the full value of instruction to be gained will not be secured. A very readable short article on the making of lantern slides is found in the February number of *The Photographic News* (English). Among other suggestions these paragraphs occur:

"For the general run of negatives intended for lantern slide work we do not require, and are far better without, excessive density. A negative which would give a printer, by reason of its thinness, much trouble when made to yield an albumen print, will generally make a good lantern slide if some little care be given to it. Indeed, so easy is it to make a strong positive from a weak negative that experts often find it convenient to do this with the sole object of obtaining from that positive a new negative of better character than the original. The chief thing in the production of a good lantern slide from a thin negative is to attend to the distance at which the printing frame is from the source of light and the duration of exposure—that is if we are printing by contact. It is also often advisable to cover the back of the negative with colored tissue paper. The same remark applies to similar negatives copied by means of the camera."

"It is a very common thing to see gelatine lantern slides with distinct evidence of the light having penetrated the dark parts of the negative, giving the pictures a very dirty appearance. It is astonishing that this fault is often apparent, considering that the means of effectually clearing up such a picture are so well known. The lantern-slide worker should always have at hand a five per cent. solution of ferricyanide of potassium. Let each slide as it comes from the fixing bath be examined, and if it should have any of these dirty parts due to light action apply to those parts, by means of a soft camel-hair brush, some of this solution, and directly as the stain is seen to disappear put the picture under the tap. The action is very rapid, and care must be taken not to overdo it. It is quite easy to blot out the entire image from a normal lantern slide, and to leave clear gelatine, so rapid is the reducing action of the ferricyanide. It need hardly be pointed out that this remedy in the hands of an artist is capable of producing some very fine effects, because he is able to eliminate or reduce at pleasure, and he can accomplish the work with the brush, the handling of which is so familiar to him. The use of a reducing agent in connection with lantern-slide production has not received the attention which it certainly merits, and we have endeavored to point out what a valuable resource it is in the case of over-printed slides."

Meteors Observed During a Total Eclipse of the Sun.—In looking over the Coast & Geodetic Survey records covering the observations of 1869 during the total solar eclipse, I incidentally gathered the following memoranda of meteors visible by different parties and at different localities. Superintendent's annual report for 1869.

I. *Meteors seen in the Telescope before Totality*—August 7, 1869, Shelleyville, Kentucky. When the eclipse had advanced half way from the first contact to totality, Alvan G. Clark, Jr., says: "His attention was called, by Professor Winlock, to small objects crossing the field of the finder, in straight lines, and supposed by both observers to be meteors. Mr. Clark himself observed about twenty of these objects," p. 136.

II. *Meteors seen with the unassisted eye during Totality.*—Falmouth, Kentucky, $6^h\ 15^m$ P. M. "During totality Mrs. Murphy saw two meteors. The first was traced from a point near the meridian and not far from the zenith towards the southeast; the course of the second was from the northwestern to the southwestern part of the sky." p. 132.

III. *Meteors seen in the Telescope soon after Totality.*—Shelleyville, Kentucky, J. Blake, Jr., Alvan G. Clark. "Soon after the re-appearance of the Sun my attention was attracted to bright points of light, which were, from time to time, passing across the field. After observing about fifteen or twenty of them,

I concluded that they passed between the Earth and the dark body of the Moon; that they always fell in the same direction, which was from the apparent upper limb of the Moon to the horizon; that their paths were straight lines, and parallel to each other; that one seen by Alvan G. Clark, Jr., through a telescope * * * was also seen by myself; and that they were incandescent bodies. In size they were equal to the smallest star visible through any telescope: about as large as a tenth or eleventh magnitude star appears to be in the Harvard College equatorial, [14.9 inches]. As the sunlight increased these meteors ceased to be visible." p. 143.

He was not looking through the telescope during the total phase.

IV. *Meteors seen in the Telescope ten to twenty-five minutes after Totality.* —Shelleyville, Kentucky, George W. Dean. "About ten minutes after the total phase I observed a faint object pass across the Moon in a southwesterly direction; in a few minutes I saw another which was soon followed by another in the same general direction. Within fifteen minutes I saw ten of these faint objects pass across the Moon. They had the appearance of being meteors, and I am inclined to believe they were." G. D.

Naked Eye View of Jupiter's Fourth Satellite.—I extract the following from my note-book, thinking they might be of use to you:

November 19, 6-12^h, while engaged in observing variable stars, a great many shooting stars were seen, presumably the Andromedes as their paths indicated a radiant in Andromeda. They perhaps averaged one every two or three minutes.

1894, December 19, 12^h, accidentally casting my eye up to Jupiter then on the meridian, what was my surprise to see a sharply defined little star close to and a little east of the planet. Satisfying myself that it was no illusion, I turned the telescope on Jupiter and identified the little star as the fourth satellite. The third satellite was on the same side of Jupiter, but too close to him to be identified with this star. Several times between that time and moon-rise, I looked up to Jupiter and the little star would persist in keeping that place, thus proving it to be a real star, and therefore the satellite. Jupiter presented very nearly a disc.

Encke's Comet.—Having no ephemeris of the comet, and as the evening of December 14 was a very fine one, I concluded to use the hour before moon-rise in searching for the comet, to see if it was not getting bright enough to be visible in my 3-inch glass. I succeeded in picking up what appeared to be an 8th magnitude star with diffuse nebulosity, and as I could not identify the object with any nebula, I suspected it of being a comet, but as the Moon soon rose it was blotted out of sight. I re-observed it the next evening, and beyond a possible doubt, could detect no change of position, and therefore, inferred that it was a nebula. The next observation was not obtained until December 18, when it was found to have moved about -1^m in R. A. and $-25'$ in Decl. Then the question arose "Is it Encke's, or is it a new one?" Having no ephemeris at hand, I was unable to tell, so I immediately wrote to Professor Keeler of Allegheney, who kindly looked the matter up and found it to be Encke's. Since then the comet has been daily increasing the rate of its motion, and also rapidly brightening so that on the evening of Jan. 1, 1895, it was quite bright even under the light of the Moon. It presents an elongated condensation in the center, and is a very interesting object. Its peculiar appearance on the first of two evenings named above, was caused by its occulting an 8th magnitude star.

The transit of Mercury and occultation of Pleiades were not seen on account of clouds and stormy weather. W. E. SPERRA.

Reflectors for Planetary Details.—In view of Mr. Lowell's statement in the February number that for planetary detail "the reflector is well-nigh worthless" it is proper to remind his readers that in the September number we find "the admirable and artistic drawings of Green are the most typical as they were also the last of any account." They were made with a reflector, and if the same observer's drawings of Jupiter be compared with those made from the Dearborn refractor they will be found very little, if any, inferior. Professor Hough the leading authority on Jovian markings, has studied them for years and has no doubt drawn everything the telescope exhibits. The drawings of Jupiter in Gore's Planetary and Stellar Studies show what the Rosse three foot metal reflector is capable of. De La Rue's Jupiter and Saturn can also decide whether Mr. Lowell is right. As for Martian detail, well known observers in Europe have seen some of the candals with 6½ in. reflectors.

It seems (and it is hoped that the eminent optician whose valuable suggestions frequently appear in these columns will render an opinion here) that Mr. Lowell would be nearer right in stating that the definition of the very large reflectors, 6 foot Rosse, 5 and 3 foot common, 4 foot Melbourne, is not so good as their aperture would imply, aside from increased atmospheric effects. But for smaller and medium apertured reflectors hundreds are in use in Europe and many in America, some of which have done and will continue to do good work in the various fields of stellar science. It is quite certain that, everything considered, the owners are well satisfied with them.

According to Chamber's excellent "Hand-book of Astronomy" the reflector should be double the aperture of the refractor for equal light power. This also is quite incorrect and on another page Vega is stated to be of green color. If the latter is the work of the author's fine 6-in. refractor then indeed for some kinds of work the refractor (and this one first of all) is well nigh worthless.

A. C. BEHR.

Occultation of the Pleiades, Dec. 10, 1894.—*Observations at the Chamberlin Observatory, University Park, Colo.*—The following observations were made by Herbert A. Howe with the 20-inch equatorial, with a power of about 300 diameters. A card was inserted in the focus of the eye-piece of the micrometer, in such a way as to cover half the field of view. The edge of this card was placed tangent to the moon's limb at the points of immersion and emersion, so as to screen the observer's eye almost entirely from the bright light of the Moon. Local mean times are given: the latitude and longitude of the Observatory are given in the American Ephemeris, opposite the name Denver. The times were noted by eye and ear, with a chronometer beating half-seconds.

		h	m	s
17 Tauri	Immersion	10	45	11.1
16 "	"	11	4	30.3
20 "	"	11	39	49.4
23 "	"	11	42	26.2
16 "	Emersion	11	57	56.1
17 "	"	12	4	28.5
24 "	Immersion	12	9	16.0
η "	"	12	14	49.8
20 "	Emersion	12	31	38.6
B. A. C. 1171	Immersion	12	48	53.6
28 Tauri	"	13	16	58.4
η "	Emersion	13	18	26.0
28 "	"	14	3	27.7

Observations were also made by students, using the 6-inch equatorial, with a

power of about 70, the times being recorded chronographically. The results follow:

			h	m	s	
17	Tauri	Immersion	10	45	11.4	H. W. Avery.
20	"	"	11	42	26.6	T. L. A. Shaffer.
24	"	"	12	9	17.8	Alice G. Plested.
η	"	"	12	14	49.9	E. M. Antram.

Of a less degree of accuracy are the following observations in which the observer signaled to two recorders, who noted the time by listening to the telegraphic beats of a clock. The observations were made with the two five inch finders of the 20-inch equatorial, except Miss Dickson's on 16 Tauri, which was made with the 6-inch equatorial, and those of Miss Daniels, which were made with a three inch instrument, having a power of 90.

			h	m	s	
17	Tauri	Immersion	10	45	12.5	R. M. Brann.
"	"	"	10	45	13.9	E. M. Antram.
16	"	"	11	4	30.0	MarthaW. Dickson.
	"	"	11	4	31.7	Alberta G. Bloom.
	"	"	11	4	32.8	Nan McFarland.
20	"	"	11	39	49.9	Grace G. Evans.
"	"	"	11	39	50.9	Alice G. Plested.
"	"	"	11	39	51.9	Mabel L. Daniels.
23	"	"	11	42	29.5	Alice G. Plested.
η	"	"	12	14	51.2	J. R. Swenson.
"	"	"	12	14	51.2	H. W. Avery.
23	"	Emersion	12	25	33.4	Martha W. Dickson.
B. A. C. 1171		Immersion	12	48	55.3	E. Morris.
28	Tauri	"	13	16	59.4	Alberta G. Bloom.
"	"	"	13	17	0.1	R. M. Brann.

The Chicago Academy of Sciences.—*Section of Mathematics, Astronomy and Physics.*—The regular monthly meeting was held at the Commerce Club, Feb. 12th, Professor G. W. Hough, President, in the Chair. The present officers were re-elected for the ensuing year. After the transaction of other business the section proceeded to the programme of the evening. Mr. J. E. Siebel presented a short paper on the "*General Equations for Refrigerating Media.*" He discussed the well-known equations of Van der Waal and found that they were applicable to an hydrous ammonia vapor.

The second paper was "*On the Variation of the Latitude,*" by Professors Hough and Crew. Professor Hough gave an historical account of latitude determinations, and cited well known facts to show that the latitudes had been sensibly constant during centuries. But several modern astronomers had suspected a small variation, and Euler had shown that the period ought to be 306 days if the Earth is a rigid body. The speaker referred to the accuracy of our best latitude determinations, and remarked on Bessel's failure to find any sensible variation. He also spoke of Newcomb's attempt to detect the same phenomenon at the request of Lord Kelvin in 1867, which was unsuccessful. The first positive indication that the latitude varied by an appreciable amount was obtained by Dr. Küstner, at Berlin, in 1884. This led to a systematic investigation of the phenomenon by several of the leading European observatories—Berlin, Prague, Potsdam, Strasburg, Pulkowa, Greenwich, etc. The result was to show that the variation is sensible, and that it must hereafter be taken into account in all fine determinations of star places. Professor Hough gave the formula of Dr. Chandler, and spoke of his remarkable discovery of the 427 day period, which was interpreted as indicating that the Earth is about as rigid as glass, as Professor Newcomb

had pointed out. The speaker gave Dr. Chandler's diagram for the motion of the pole of the Earth, and several diagrams for the variation of the latitude at particular places. He said that although the variation of the latitude was found to be sensible, it was apparently periodic, and that if any secular variation existed it must be very slight, as the latitude of an Observatory such as Paris had not varied as much as one second in a hundred years. This would preclude the idea of any large wandering of the axis of rotation in the body of the Earth.

Professor Crew discussed the phenomenon from a dynamical standpoint. After deriving the equations for the positions of the principal axes of the Earth, he showed how the rotation would be stable about the axis of maximum or minimum moment of inertia. The discussion was illustrated by diagrams which showed the path the pole would pursue in case of the rotation of a cube, a spheroid, etc. The speaker then took up Maxwell's dynamical top, and illustrated the phenomenon experimentally. The apparatus is so constructed that the moments of inertia can be varied by the use of screws, and the phenomenon of the variation of the latitude was beautifully illustrated. Considerable informal discussion followed the reading of the paper. Professor Chamberlain thought the variation of the latitude furnished a crumb of comfort to Geologists, as a secular variation might enable them to better explain the Ice Age in North America. Dr. See called attention to Laplace's discussion of the variation of the latitude in the fifth volume of the *Mecanique Celeste*, and thought the great author had there clearly indicated why any large secular variation must be rejected. He referred also to Darwin's investigation as proving that if any secular variation had taken place, it could not be large. *G.*

BOOK NOTICES.

A Treatise on Plane and Spherical Trigonometry. By E. Miller, Professor of Mathematics and Astronomy in the University of Kansas. Second edition. Publishers, Messrs. Leach, Shewell & Sanborn, Chicago.

This edition of Miller's trigonometry is, at sight, an attractive one, in the essentials of a text-book. The matter, arrangement and the print of the page leave little that is important to be desired. In the introductory part it is concise and thorough. The spherical part is quite complete though not as full in detail as some other texts. The applications of spherical trigonometry to astronomy are unusually full. In this particular the book furnishes an excellent preparation for introductory study on the mathematical side in college training.

Professor Miller has done good work in preparing this book and the publishers have presented his matter substantially and most handsomely.

Astronomische Chronologie by Walter F. Wislicenus, Professor at the University of Strassburg. Publisher, B. G. Teubner, Leipzig. 1895. pp. 164. Price 5 marks.

To those who read the German this new book on astronomical chronology will be welcome. It is a plain and interesting statement of facts and methods pertaining to the subject matter in hand. Students of astronomy ought to read it.

The Blue Book of Amateur Photographers, also the British Edition, both edited by Walter Sprague.

The two books in blue paper covers make a very complete and very useful hand-book and directory for all interested in photography. The arrangement of matter for convenience is all that could be desired and the variety of information is unexpectedly great. The many illustrations of the text are beautiful specimens of the modern photographic art.